
HELIOS

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A Compilation of Boiler Room Engineering Information

Published by

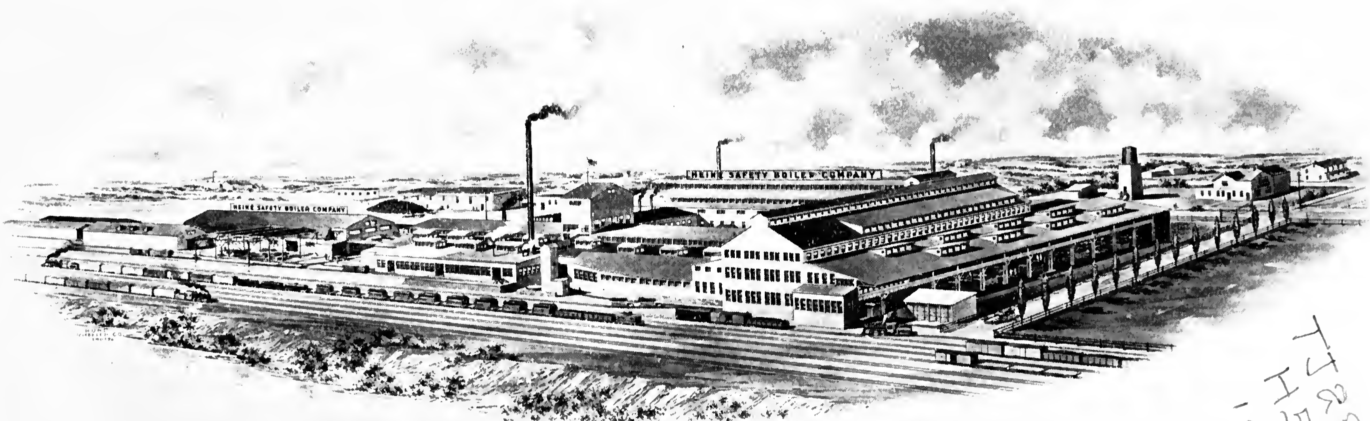
HEINE SAFETY BOILER CO.

Manufacturers of

Water Tube Boilers

SAINT LOUIS

1912



PHOENIXVILLE, PA., SHOP *of the* HEINE SAFETY BOILER CO.

Heine Safety Boiler Co.

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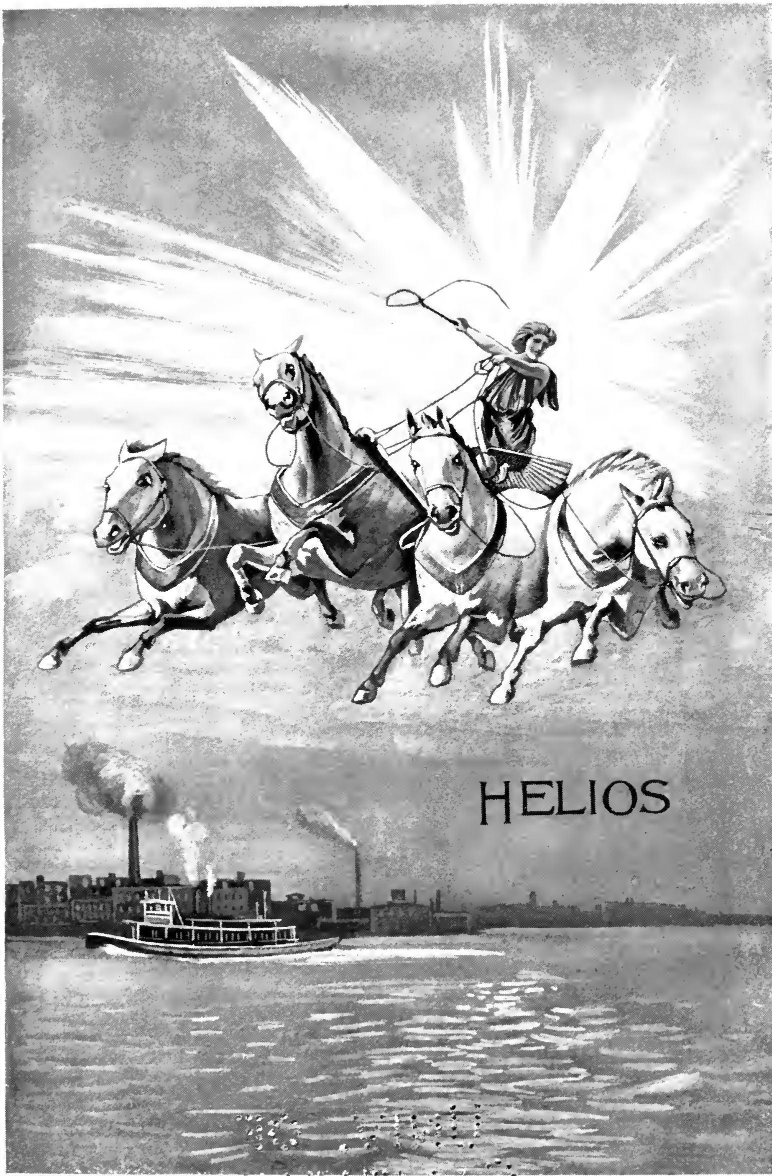

HELIOS

Preface to Eleventh Edition.

SINCE Helios was first published, eighteen years ago, many changes in engineering practice have come about, and many of the previously accepted constants which were based on experimental data, have been changed as the result of more refined methods of determination. In order to bring everything up to date the entire text has been rewritten and a determined effort has been made to have all data authentic and accurate. We feel no hesitancy in commending the book as worthy of confidence and for ready reference, to every one who may find use for the material which it contains.

As Helios falls into the hands of all classes of those interested in steam engineering, its scope must be broad, and much of the text will therefore appear elementary to some, but there will doubtless be something of interest to all.

The main value of the book to us lies in its value to others and while it is issued primarily as a piece of advertising literature most of the matter relating to the Heine Boiler has been grouped in the back pages.

St. Louis, January 1, 1912.

HELIOS

Source of All Power! Fountain of Light and Warmth!

Adored by the ancient husbandman as the God who blessed his labors with a harvest of golden grain; revered by the early sage as the great visible means of the divine creative force; pictured by the inspired artist as the tireless charioteer who drives his four fiery steeds daily across the heavens, his head circled by a crown of rays, his chariot wheel the disk of the sun itself.

When primeval man began to think, the sun seemed to him the cause of all those wonders in nature which ministered to his simple wants, or taught his soul to hope. His crude feelings of awe and gratitude blossomed into worship, and we find the sun as central figure in all early religions. He was the Suraya of the Hindoos, the Baal of the Phoenicians, the Odin of the Norsemen, and his temples arose alike in ancient Mexico and Peru. As Mithras of the Parsees, he was adored as the symbol of the Supreme Deity, his messenger and agent for all good. As Osiris he received the worship and offerings of the Egyptians, whose priests, early adepts in the rudiments of science, saw in him the cause of the annual fructifying overflow of the Nile.

Modern knowledge, with its vast array of facts and figures, can but verify and seal the faith of these ancient observers. What they dimly discerned as probable is now the central fact of physical science. From him are derived all the forces of nature which have been yoked into the service of man. All animal and plant life draws its daily sustenance from the warmth and light of the sun, and it is but his transmuted energy we expend, when, with muscle of man or horse, we load our truck or roll it along the highway.

Do we irrigate the soil from the pumps of a myriad windmills? His rays, on plains far inland, supply the energy for the breeze which turns their vanes. Does a lumbering wheel drive a dozen stamps and a primitive arastra in some Mexican canyon? Do mighty turbines whirl a million flying spindles and shake thousands of clattering looms on the banks of some New England stream? From the bosom of the ocean and the swamps of the tropics, Helios lifted those vapory Titans whose lifeblood courses in the mountain torrent and the river of the plain. Do a hundred cars rattle up the steep streets of the smiling city by the Golden Gate? Are massive ingots of steel forged to shape and size by the giant hammers of Bethlehem? The fuel which gives them motion was stored for us, ages before man was evolved, by the rays which flash from his chariot wheels! "The heat now radiating from our fire places has at some time previously been transmitted to the earth from the sun. If it be wood that we are burning, then we are using the sunbeams that have shone on the earth within a few decades. If it be coal, then we are transforming to heat the solar energy which arrived at the earth millions of years ago."

Professor Langley remarks that "the great coal fields of Pennsylvania contain enough of the precious mineral to supply the wants of the United States for a thousand years. If all that tremendous accumulation of fuel were to be extracted and burned in one vast conflagration, the total quantity of heat that would be produced would, no doubt, be stupendous, and yet," says this authority, who has taught us so much about the sun, "all the heat developed by that terrific coal fire would not be equal to that which the sun pours forth in the thousandth part of each single second."

The almost limitless stores of petroleum which are found in America and in Asia, and the smaller, though still vast supplies of natural gas which some favored localities are now exploiting, represent but so much sun-energy transmuted through forests of prehistoric vegetation.

Another authority tells us that the total amount of living force "which the sun pours out yearly upon every acre of the earth's surface, chiefly in the form of heat, is 800,000 horse-power." And he estimates that a flourishing crop utilizes only 4-10 of 1 per cent of this power.

Remembering, then, that this sun-energy reaches us only one-half of each day, we may, *whenever we learn how*, pick up on every acre an average of 175 horse-power during each hour of daylight, as a surplus which nature does not require for her work of food production.

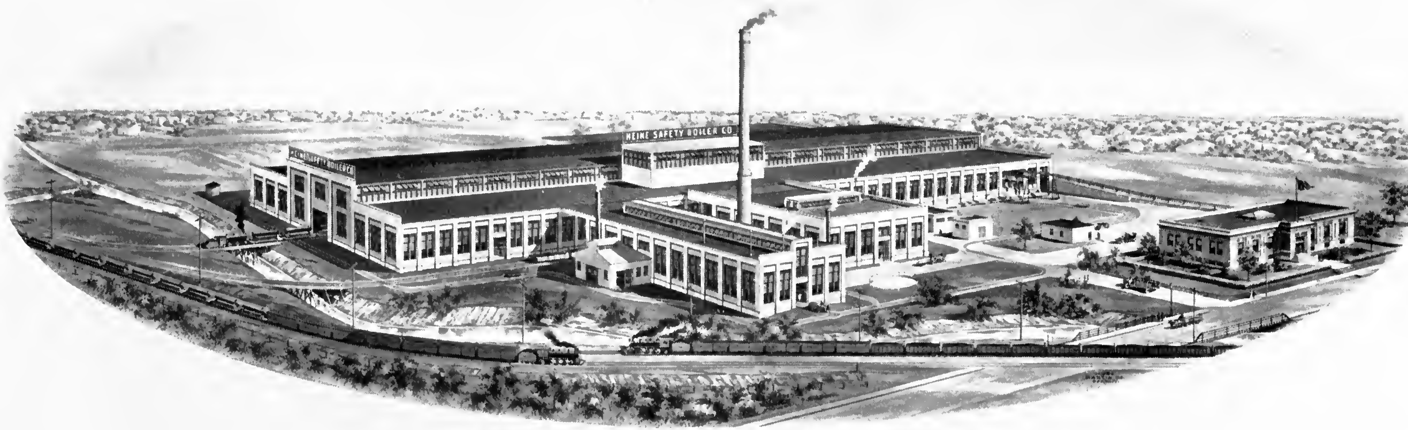
Attempts to utilize this daily waste have been made, and future inventors may fire their boilers directly with the radiant heat of the sun. But whether we depend on what he garnered for us ages ago, or quite recently, or on the stores he will lavish on us in the future, it is clear that man's continued existence on earth is directly dependent on Helios.

In olden times the various trades or guilds chose as their patron saint some prominent person who was thought to have embodied in his life-work the special means and methods of their craft. By that token we claim Helios as our own. He has always carried the record for evaporative efficiency. He provides both the fuel and the water for our boilers. He teaches us perfect circulation, upward as mingled vapor and water by the action of heat, and down again by gravity as rain and river in solid water. It is therefore fit that the boiler in which this perfect and unobstructed circulation is made the leading feature of construction should have HELIOS as its emblem.

In the following pages we give some account of the fuels used in the practical arts, of the water which becomes the vehicle for transmitting their energy into mechanical power, and of the limitations imposed by their varying conditions. These must all be taken into account in estimating how much we may expect of certain combinations of machinery.

We trust that the tables and data may be found convenient for ready reference alike by professional men, by manufacturers, and by that growing class of practical steam engineers who realize that true theory, consonant with collective experience, is within the reach of every thoughtful man who pulls the throttle. E. D. MEIER.

This explanation of the choice of the word HELIOS, as the name of this book, appeared as the preface of the first edition in July, 1893, and the word has ever since been a prominent feature of our trade mark.



ST. LOUIS, MO., SHOP *of the* HEINE SAFETY BOILER CO.

HELIOS

HEAT.

THEORY OF HEAT.

PROBABLY the first scientific hypothesis concerning the theory of heat was promulgated by Bacon, who described heat as being a vibratory motion of the smallest parts of bodies and this view seems to have been accepted largely, until the latter part of the 17th century, when it was replaced, partly at least, by the suggestion that heat is an imponderable chemical substance, the reading of which theory is now both interesting and amusing. In 1789, however, Benjamin Thompson, Count Rumford, conducted very extensive and exhaustive experiments for the Bavarian government in the Arsenal at Munich, Bavaria, which were discussed by him in a paper presented to the Royal Society of Great Britain. He stated that heat is not a substance, as it was at that time regarded, but that it is a form of energy, caused by a vibratory motion of the atoms or molecules of a body. Thompson's deductions have been verified by many other distinguished investigators, and from the various results, have been deduced the now accepted doctrine of the "conservation of energy," and the more important one of the determination of a definite measurable relation between the two forms of energy, heat and work.

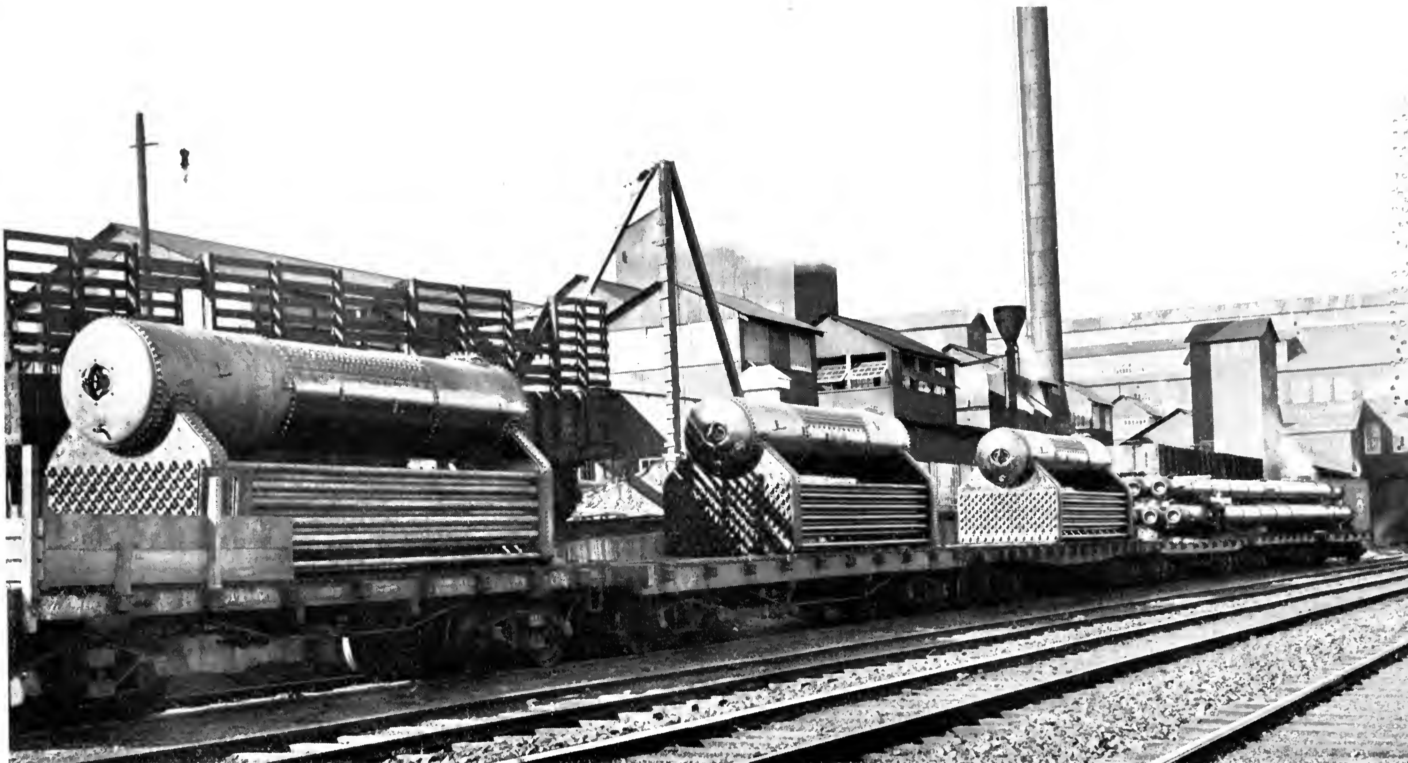
Heat as a form of energy is subject to the laws which govern every other form of energy and which control all matter in motion, whatever such motion be, molecular or of masses.

Most lines of manufacture are directly dependent in some way upon the agency of heat, so that it is of great importance to acquire as much knowledge as possible of its varied sources, and of the physical and chemical laws governing its economical production and use.

HEAT MEASUREMENTS.

Quantities of heat are measured as follows:

In the "English System," by the British Thermal Unit (B. T. U.), which is the quantity of heat required to raise one pound of pure water one degree (1°) F. from 62° F. 63° F.



SHIPMENT OF HEINE BOILERS AND SPECIAL WORK LEAVING SHOP AT PHOENIXVILLE, PA.

In the "French or Metric System," by the Calorie (Cal.), which is the quantity of heat required to raise one kilogramme of pure water 1°C. from 15°C. to 16°C.

HEAT CONVERSION.

Heat may be converted, as the result of either physical or chemical action, into any other form of energy, and another form of energy may be, in a like manner, converted into heat, all such conversions being in calculable amounts.

Nearly all physical phenomena, in fact, involve heat transformation or conversion in one form or another, and in a greater or less degree, under the laws of energetics.

According to the first of those laws, such changes must always occur in a definite ratio, and when heat disappears in known quantities it is always certain that energy of some kind in calculable amount will appear as its equivalent; the reverse is as invariably the case when heat is produced; it always represents and measures an equivalent amount of mechanical, electrical, chemical or other energy expended.

MECHANICAL EQUIVALENT OF HEAT.

Dr. Joule, from 1843 to 1849, made an elaborate series of experiments, and established the fact that heat converted into work or *vice versa*, was always in definite quantivalence, and also determined that one heat unit was the equivalent in work of 772 ft. lbs., but more recent experiments have resulted in the establishment of 778 ft. lbs., as the "mechanical equivalent" of one B. T. U.

A weight of 778 lbs. falling through a distance of 1 ft. develops energy equivalent to 1 B. T. U., which is the quantity of heat required to raise 1 lb. of water 1°F. as above stated.

In the French system 424 kilogram meters is the mechanical equivalent, since the weight 424 kilo. falling through a distance of one meter developes energy equivalent to one Calorie, which is the quantity of heat required to raise one kilo. of water 1°C.

This relation of work done, to heat generated, or *vice versa*, is commonly stated as the first principle of Thermodynamics.

The commonly recognized English unit of work is the "Horse Power," which was established by James Watt, as being 33000 lbs. raised one foot in one minute.

The French or Metric unit of work is the "Cheval Vapeur," which is the equivalent of 4500 kilogrammes, raised one meter in one minute.

The unit of electrical work is the Watt, and 746 Watts is the equivalent of one English H. P.

Tables No. 1 and No. 2 give a comparison of the commonly used English and Metric units.

Table No. 1

1 B. T. U. =	0.2520	Calorie	1 Calorie =	3.9683	B. T. U.
" " " " =	778.	Ft. lbs.	" " =	3087.3	Ft. lbs.
" " " " =	0.023575	H. P.	" " =	0.09355	H. P.
" " " " =	17.5869	Watts	" " =	69.785	Watts
" " " " =	107.5196	Kilogrammeters.	" " =	426.64	Kilogrammeters
" " " " =	0.2389	Cheval Vapeur	" " =	0.09482	Cheval Vapeur
1 H. P. =	33000	Ft. lbs.	1 Cheval Vapeur =	32535.	Ft. lbs.
" " " =	42.416	B. T. U.	" " " =	41.846	B. T. U.
" " " =	746.	Watts	" " " =	735.99	Watts
" " " =	10.6886	Calories	" " " =	10.545	Calories
" " " =	4550.55	Kilogrammeters	" " " =	4500.	Kilogrammeters
" " " =	1.0136	Cheval Vapeurs	" " " =	0.9863	H. P.

Table No. 2

1 B. T. U. per sq. ft.	=	2.713	Cals. per sq. meter
1 Cal. per sq. meter	=	0.369	B. T. U. per sq. ft.
1 B. T. U. per lb.	=	0.556	Calorie per kilogramme
1 Calorie per kilogramme	=	1.80	B. T. U. per lb.

HEAT DEFINITIONS.

The *Total Heat of a substance* is the sum of the latent heat and of the sensible heat measured from some definite temperature and state.

Sensible Heat is that portion of the total heat of any body, which can be felt or which is made evident by a rise in temperature.

Latent Heat is that which manifests itself in some manner other than in the change of temperature, either as change of *volume*, as when iron is heated, or of *state*, as when a solid changes into a liquid or a liquid into a gas. The most common examples, illustrating the difference between latent heat and sensible heat, is the melting of ice and the boiling of water, in which cases a change of state takes place, requiring heat, but without a change in temperature.

If heat be applied to a block of ice in an open vessel, its temperature begins to rise and continues until 32°F. (0.00°C.) is reached, at which point the ice begins to melt. Continue the heating and the melting continues, but without any further rise of temperature, the heat being

absorbed and used up in producing and continuing the melting and the thermometer will continue to stand at 32°F., until the ice is all melted and we have water at 32°F.

The heat absorbed, in thus changing the mass from ice (a solid) into water (a liquid) at 32°F. and at atmospheric pressure is 142.6 B. T. U. per lb. and is called the "latent heat of fusion of ice."

If the application of heat continues, the water at once commences to rise in temperature, continuing to do so until 212°F. (100°C.) is reached, when the formation of steam commences. Continuing the heating, the boiling continues, but no rise of temperature is produced, the heat thus added to the water being utilized in changing the liquid (water) into steam (a gas), and as it is impossible to heat water above 212°F. under atmospheric pressure, the steam will continue to pass off at 212°F. until all the water has been evaporated. In this change of state, from water (a liquid) into steam (a gas) 970.4 B. T. U. per lb. have been absorbed and this quantity is designated "latent heat of evaporation of water."

Table No. 3

LATENT HEAT OF FUSION OF VARIOUS SOLIDS.

Beeswax	76.14 B. T. U.	Paraffine	63.27 B. T. U.
Bismuth	22.75 " " "	Phosphorus	9.06 " " "
Ice	142.6 " " "	Silver	37.93 " " "
Iron grey, cast	41.40 " " "	Spermacetti	66.56 " " "
" white "	59.46 " " "	Sulphur	16.86 " " "
Lead	9.66 " " "	Tin	25.65 " " "
"	10.55 " " "	Zinc	50.63 " " "
Mercury	5.08 " " "		

EXPANSION BY HEAT.

Probably the most common and familiar example of the action of heat upon a body is the change of volume or length which results.

Almost every substance grows larger when heated. The amount of change differs in different substances. Table No. 7 gives the "co-efficient of expansion" of various substances. This term means simply the change of dimension of unit size of a substance with a one degree change in temperature.

RADIANT HEAT.

Heat is radiated from hot bodies in all directions and to an indefinite distance. Heat rays follow a direct path and their intensity varies inversely as the square of distance.

BROAD ST. STATION, PA. R. R. CO., PHILADELPHIA, PA.
CONTAINS 2,000 H. P. OF HEINE BOILERS.

Table No. 4

LATENT HEAT OF EVAPORATION OF VARIOUS LIQUIDS.

Alcohol ethyl	371.0	B.	T.	U.
" methyl	481.	"	"	"
Ammonia	529.	"	"	"
Bisulphide of Carbon	162.	"	"	"
Ether	162.8	"	"	"
Wood Spirits	474.	"	"	"
Sulphur dioxide	164.8	B.	T.	U.
Sulphuric ether	175.	"	"	"
Turpentine	133.	"	"	"
"	124.	"	"	"
Water	970.4	"	"	"

Table No. 5

APPROXIMATE MELTING POINTS OF VARIOUS SUBSTANCES.

Acid Acetic	113°F
" Carbonic	108°F
" Sulphuric	240°- 590°F
" Sulphurous	148°F
" Stearic	158°F
Aluminum	1157°-1213°F
Antimony	810°-1150°F
Bismuth	504°-514°F
Brass	1859°F
Bromine	9.5°F
Bronze	1652°-1690°F
Cadium	442°F
Copper	1929°-1996°F
Delta Metal	1742°F
Glass	1832°-2377°F
Pure Gold	1943°-2282°F
Gunmetal	1700°F
Ice	32°F
Iron, grey cast	2012°-2228°F
" white "	1922°-2075°F
" wrought"	2732°-2912°F
" pure "	2975°F
Lard	95°F
Lead	608°- 617°F
Manganese	3452°F
Magnesium	1200°F
Mercury	—39°F
Nickel	2732°F
Nitro Glycerine	45°F
Pitch	91°F
Phosphorus	112°F
Platinum	3227°-3452°F
Potassium Sulphate	1859°F
Potassium	136°- 144°F
Saltpetre	606°F
Silver	1733°-1873°F
Sodium	194°- 208°F
Spermacetti	120°F
Stearine	109°- 120°F
Steel (hard)	2570°F
Steel (mild)	2687°F
Sulphur	239°F
Tallow	92°F
Tin	442°- 446°F
Turpentine	14°F
Wax (rough)	142°F
Wax (bleached)	154°F
Zinc	773°- 779°F

Table No. 6

BOILING POINTS OF VARIOUS SUBSTANCES AT ATMOSPHERIC PRESSURE (14.7 LBS. PER SQ. IN.)

Sulphuric Ether	100°F
Carbon Bisulphide	118°F
Ammonia	140°F
Chloroform	140°F
Bromine	145°F
Wood Spirits	150°F
Alcohol	173°F
Benzine	176°F
Naphtha	186°F
Water	212°F
Mercury	676°F
Average Sea Water	213°F
Saturated Brine	226°F
Nitric Acid (S. G. 1.42)	248°F
Turpentine (oil)	315°F
Phosphorus	554°F
Coal Tar	325°F
Petroleum rectified	316°F
Sulphur	570°F
Sulphuric acid (S. G. 1.848)	590°F
Linseed oil	597°F

Table No. 7

LINEAL EXPANSION OF SOLIDS AT ORDINARY TEMPERATURES.

Substance.	For 1°F	For 1°C
	Length=1	Length=1
Aluminum (cast)	.00001234	.00002221
Antimony (cryst)	.00000627	.00001129
Bismuth	.00000975	.00001755
Brass (cast)	.00000957	.00001722
Brass (English plate)	.00001052	.00001894
Brass (sheet)	.00001040	.00001872
Brick (best stock)	.00000310	.00000550
Bronze (Baileys) Copper, 17; Tin 2½; Zinc 1	.00000986	.00001774
Zinc	.00000975	.00001755
Cement, Roman Dry	.00000797	.00001435
" Portland, pure	.00000594	.00001070
" " with sand	.00000656	.00001180
Concrete, cement, pebbles	.00000795	.00001430
Copper	.00000887	.00001596
Ebonite	.00004278	.00007700
Glass, English flint	.00000451	.00000812
" French "	.00000484	.00000872
" white, free from lead	.00000492	.00000886
" blown	.00000498	.00000896
" thermometer	.00000499	.00000897
" hard	.00000397	.00000714
Granite, grey, dry	.00000438	.00000789
" red "	.00000498	.00000897
Gold, pure	.00000786	.00001415
Iridium, pure	.00000356	.00000641
Iron, wrought	.00000648	.00001166
" Swedish	.00000636	.00001145
" cast	.00000556	.00001001
" soft	.00000626	.00001126
Lead	.00001571	.00002828
Marble, moist	.00000663	.00001193
" dry	.00000363	.00000654
" white, Sicilian, dry	.00000786	.00001415
" black, Galway	.00000308	.00000554
" Carrara	.00000471	.00000848
Masonry, brick, in cement, headers	.00000494	.00000890
" " " " stretchers	.00000256	.00000460
Nickel	.00000695	.00001215
Pewter	.00001129	.00002033
Plaster, white	.00000922	.00001660
Platinum	.00000479	.00000863
Platinum, 90% Iridium 10%	.00000476	.00000857
" 85% " 15%	.00000453	.00000815
Porcelain	.00000200	.00000360
Silver, pure	.00001079	.00001943
Slate	.00000577	.00001038
Steel, cast	.00000636	.00001144
" tempered	.00000689	.00001240
Stone,sandstone, dry	.00000652	.00001174
" " Rauville	.00000417	.00000750
" " Caen	.00000494	.00000890
Tin	.00001163	.00002094
Wood, pine	.00000276	.00000496
Zinc 8%-Tin 1	.00001496	.00002692

The rate at which the hot body may radiate or at which the colder body may receive heat, depends upon the surfaces, as well as upon their temperatures. Dark rough surfaces will both radiate and absorb heat at a higher rate than if they are smooth, especially so if polished. A hot body will radiate the same quantity of heat that it can absorb under the same conditions.

If a body having a polished surface is struck by a ray of heat, part of the ray becomes absorbed and the rest is reflected. Therefore the reflecting power of any body is the complement of its absorbing power, as well as of its radiating power. The co-efficient of radiation, as established by Peclet, gives the number of heat units emitted per hour, per sq. ft. of surface for each 1°F. difference of temperature, or the number of calories emitted per hour, per sq. meter for each 1°C. difference of temperature, as shown by table No. 8.

Table No. 8

CO-EFFICIENTS OF RADIATION.

Surface.	B. T. U. per 1°F. per sq. ft. per hour.	Calories per 1°C. per sq. meter per hour.
Silver, polished	.02657	.13
Copper, "	.03270	.16
Tin "	.04395	.22
Tinned iron "	.08585	.42
Iron sheet "	.0920	.45
Iron, ordinary	.5662	2.77
Glass	.5948	2.91
Cast iron, new	.6480	3.17
" " rusted	.6868	3.36
Sawdust	.7215	3.53
Sand, fine	.7400	3.62
Water	1.0853	5.31
Oil	1.4800	7.24

The above co-efficients of radiation are practically correct for cases where differences of temperature do not amount to 10° or more. When, however, there is a difference of temperature of 10° and upwards between the heated body and the surrounding substances, the rate becomes greater, and when calculating the number of heat units, which will be radiated from a given area and material, the result should first be calculated by the co-efficients in the above table, and the value thus obtained, be multiplied by the proper ratio, which will be found in the table No. 9.

The views of Heine Boiler plants shown herein illustrate very forcibly, the wide variety of interests to which these boilers are applicable. It is impracticable to give examples of all, as there are too many different lines of industry using them.

PILLSBURY FLOUR MILLS ("A" MILL), MINNEAPOLIS, MINN., CONTAINS 2500 H. P. OF HEINE BOILERS.

Table No. 9

RATIO OF INCREASE IN RADIATION.

Diff. in Temp.	Ratio		Diff. in Temp.	Ratio		Diff. in Temp.	Ratio
Degrees	F.	C.	Degrees	F.	C.	Degrees	F.
10	1.15	1.16	160	1.61	2.20	310	2.34
20	1.18	1.21	170	1.65	2.31	320	2.40
30	1.20	1.25	180	1.68	2.42	330	2.47
40	1.23	1.30	190	1.73	2.54	340	2.54
50	1.25	1.36	200	1.78	2.66	350	2.60
60	1.27	1.42	210	1.82	2.79	360	2.68
70	1.32	1.48	220	1.86	2.93	370	2.77
80	1.35	1.54	230	1.90	3.07	380	2.84
90	1.38	1.60	240	1.95	3.23	390	2.93
100	1.40	1.68	250	2.00		400	3.02
110	1.44	1.75	260	2.05		410	3.10
120	1.47	1.83	270	2.10		420	3.20
130	1.50	1.90	280	2.16		430	3.30
140	1.54	2.00	290	2.21		440	3.40
150	1.57	2.09	300	2.27		450	3.50

The relative radiating or absorbing and reflecting power of various substances is shown in table No. 10.

Table No. 10

HEAT RADIATING, ABSORBING AND REFLECTING POWERS.

Substance.	Absorbing or radiating power.	Reflecting power.
	per cent.	per cent.
Lampblack	100	0
Water	100	0
Carbonate of lead	100	0
Writing paper	98	2
Ivory, jet, marble	93 to 98	7 to 2
Ordinary glass	90	10
Ice	85	15
Gum lac	72	28
Silverleaf on glass	27	73
Cast iron, bright, polished	25	75
Mercury, about	23	77
Wrought iron, polished	23	77
Zinc, polished	19	81
Steel, polished	17	83
Platinum, polished	24	76
" in sheet	17	83
Tin	15	85
Brass, cut, dead polish	11	89
Brass, bright, polished	7	93
Copper, varnished	14	86
Copper, hammered	7	93
Gold	5	95
Gold, plated	5	95
" on polished steel	3	97
Silver, polished	3	97

Table No. 11 shows results on the radiating power of cast iron when finished in different ways, both in clean condition and oiled, from which it will be seen that while oiling appears to produce no effect upon rough surfaces, it more than doubles the radiation from any finished surface.

Table No. 11

RADIATING POWER OF CAST IRON.

Surface	Oiled	Dry
Rough	100	100
Planed	60	32
Drawfiled	49	20
Polished	45	18

CONDUCTION OF HEAT.

Conduction is the progress of heat between two bodies, which are in constant contact with each other.

Internal conduction is the transference of heat within a body from one particle to another; for example, when heat is applied to one side of a plate of metal, its passage through the metal to the other side may be termed "internal conduction."

External conduction may be defined as the transfer of heat between two separated bodies, placed in contact with each other.

The rate of conduction is, of course, proportional to the area of the section through which it takes place and may be expressed in B. T. U. per sq. ft. per hour.

Internal conduction varies with the heat conductivity of the particular substance under consideration. It is, however, directly proportional to the difference between the temperatures of the two surfaces of a layer and inversely as its thickness. Table No. 12 gives the co-efficients of heat transmission in both British and Metric systems. These co-efficients are established for a difference of 1°F. at about 200°F., and although they vary somewhat with the temperature are sufficiently accurate for ordinary use.

External conduction taking place between the surface of a solid and a liquid is also approximately proportional to the difference of temperatures. When such difference of temperatures is considerable the rate of conduction increases faster than the simple ratio of that difference. (*Rankine.*)

Table No. 12

CO-EFFICIENTS OF HEAT TRANSMISSION.

Substance	Metric	British
Aluminum	.00036	.00203
Antimony	.0004	.00022
Brass, yellow	.00025	.00142
Brass, red	.00028	.00157
Copper	.00072	.00404
German silver	.00009	.00050
Iron	.00016	.00089
Lead	.00008	.00045
Mercury	.00002	.00011
Steel, hard	.00006	.00034
Steel, soft	.00011	.00062
Silver	.00109	.00610
Tin	.00015	.00084
Zinc	.00030	.00170

CONVECTION.

Convection means "to carry", and in this restricted sense means the "mode by which heat is propagated through a liquid by the portion heated becoming lighter and ascending to the surface, its place being taken by a colder portion descending." The conduction of heat through a stagnant mass is very slow in liquids and nearly inappreciable in gases, and it is only by the continual circulation and mixture that uniformity of temperature can be maintained in fluids or any transfer of heat occur between the containing solid and the fluid. In the case of the transfer of heat from one fluid to another through an intervening solid body, the free circulation of both of the fluids is necessary, and the transfer is often increased by having such circulation take place in opposite directions.

SPECIFIC HEAT.

The heat absorbing capacity of substances varies greatly, and may be defined as the quantity of heat required to be absorbed to raise their temperature 1°. This is sometimes called the "thermal capacity", and in order to compare the relative heat capacities of different bodies it is necessary to refer all to the same base. For this base the quantity of heat required to raise a pound of water one degree at its point of greatest density, has been selected and its value is stated at 1.000 (unity).

The ratio of the heat required to raise a pound of any body or substance one degree, to that of water (1.0) is called the "specific heat of the substance", or the "co-efficient of thermal capacity."

The specific heat of all bodies gradually increases as the temperature rises, and as given in tables No. 13, 14, 15, means the specific heat at customary working temperatures, and "mean specific heat" is the average value of this quantity between temperatures stated. The actual specific heats often vary greatly, as given by different authorities, probably from the fact that the determinations have been made at different temperatures.

The tables giving the specific heat of various substances have been collected from many sources, and may be found useful in many calculations.

Table No. 13

SPECIFIC HEAT OF SOLIDS.

Substance	Co-efficient	Substance	Co-efficient
Anthracite coal	.2017	Lime Sulphate	.1966
Antimony	.0508	Lead "	.0872
	.2134		.0314
Aluminum	.2181	Magnesia	.222
	.2185	Magnesian Limestone	.217
Bismuth	.3080		.2174
Brickwork, about	.20	Magnesium	.2499
Brass	.0939	Manganese	.1217
Cadmium	.0567	Marble	.2100
Chalk	.2410		.2129
Charcoal	.2415	Mercury, solid	.0314
	.20	" liquid	.0333
Coal	.241	Nickel	.1086
	.2777	Oak wood	.570
Coke	.2031	Pine "	.467
Copper	.0951	Pear "	.500
(from 32°-212°F)	.094	Phosphorus	.1887
(" " 572°F)	.1013		.2503
Corundum	.198	Porcelain	.1980
Diamond	9.1469	Platinum	.0324
Fir wood	.651	(32°-446°F)	.3333
Glass	.1977	Quartz	.1880
	.1937	Quicklime	.2169
Gold	.0323	Sand (river)	.1950
Graphite	.2008	Silica	.1910
	.202	Silver	.057
Natural Graphite	.2019	Soda	.2311
Ice	.504	Steel (hard)	.1175
Iridium	.0326	" (soft)	.1165
Iron wrought	.1138	Sulphur	.1777
" " (32°-212°F)	.1098		.2028
" " " 392° "	.115	Stones (gene)	.20
" " " 572° "	.1218	Tin	.0562
" " " 662° "	.1255	Zinc	.0956
" " " 200° "	.1129		
" " " 600° "	.1327		
" " " 2000° "	.2619		

NOTE:—Where more than one number is given, it signifies that authorities differ.

Table No. 14

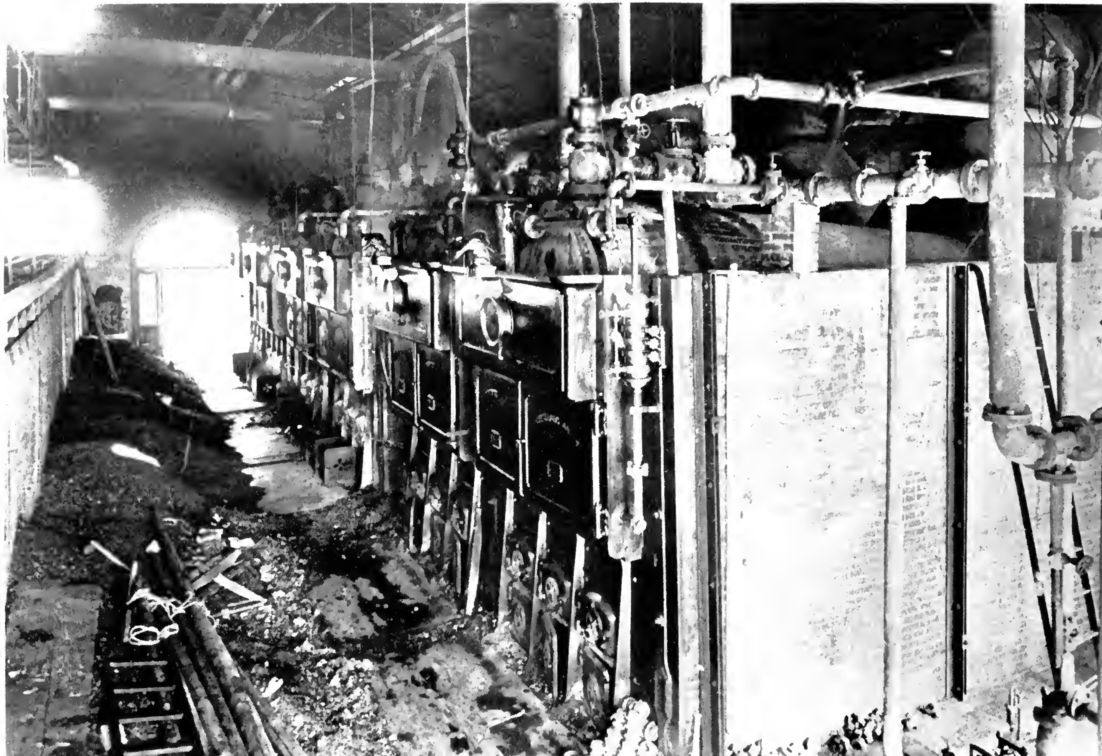
SPECIFIC HEAT OF LIQUIDS.

Liquids	Co-efficient	Liquids	Co-efficient
Acetic acid	.6590	Olive Oil	.3096
Alcohol	.6150	Sulphuric Acid	.3350
" absolute	.7000	" "	.3430
Benzine	.3932	" density 1.87	.3346
"	.4500	" " 1.30	.6614
Bismuth (melted)	.0308	Sulphur (melted)	.2340
Bromine	1.1110	Tin (melted)	.0637
Ether	.5030	Turpentine (oil)	.4260
"	.5034	Vinegar	.4720
Fusil Oil	.5640	Water at 32°F	1.0000
Hydrochloric acid	.6000	" " 212°F	1.0130
Glycerine	.5550	" 32°-212°F (Mean)	1.0050
Lead (melted)	.0402	Wood Spirits	.6009
Mercury	.0333		

Table No. 15

SPECIFIC HEAT OF GASES.

Gases	Co-efficient	
	Constant Pressure	Constant Volume
Air	.2376	.16847
Acetic Acid	.4125	
Alcohol	.4534	.3200
Ammonia	.508	.299
Blast Furnace	.2277	
Carbonic Acid	.217	.1535
" "	.2025	
" Allyride	.2163	
" Oxide	.2450	
" "	.2479	.1758
" "	.2884	
Chlorine	.1210	
Chloroform	.1567	
Ether	.4797	.3411
Hydrogen	3.2936	
"	3.4090	2.41226
Nitrogen	.2438	
"	.2754	
Nitrous Acid	.2369	
Oxygen	.2175	.15507
"	.2361	
Olefiant	.4040	.173
Steam	.4805	
Steam, superheated	.4805	.3460
Sulphurous Acid	.1553	.1246



SIX 200 H. P. HEINE BOILERS. YUBARI MINE, HOKKAIDO COLLIERY AND STEAMSHIP CO., HOKKAIDO, JAPAN.

TEMPERATURE.

Temperature is the word used to describe the condition of a body as regards heat or cold, or the relation of a body to the heat it may contain, as shown by its greater or less tendency to part with such heat.

Temperature is also a measure of molecular motion, and the more violent or rapid such motions become, the higher the temperatures become.

Temperature has no connection with and gives no information about the amount of heat in a body. If a hot body be placed in contact with a colder body, it gives up part of its heat to the colder body, until both become of the same temperature, thus proving that heat may be transferred from one body to another as already stated, but if the originally hotter body be larger or if it possesses a greater capacity for heat than the originally colder body, it will still contain, when both bodies have become of the same temperature, a very much larger quantity of heat, as stated in B. T. U., than the smaller one.

Temperatures are measured by arbitrary scales based upon the familiar phenomena of the melting of ice and boiling of water. At sea level where the atmospheric pressure is approximately 14.7 lbs. per sq. in., which is equivalent to 29.922 inches of mercury as measured by the barometer, these physical changes in the state of water always occur at the same temperature. There are several "scales of temperature" in more or less common use.

For measuring temperatures up to about 1000°F., mercury is the most frequently used, as seen in the ordinary thermometers, which are made in varying degrees of accuracy and range. Mercury is particularly well adapted for use in thermometers on account of its high boiling and its low freezing temperatures, and its high co-efficient of expansion.

For temperatures ranging up to about 500°F., the tube or space above the bulb of a thermometer is a vacuum. For higher temperatures up to 1000°F., this space is filled with nitrogen gas under pressure.

There are three well-known scales for mercurial thermometers, two of which, Fahrenheit and Centigrade, are in common every day use, while the third, Reaumer, is practically discarded. Tables Nos. 16 and 17 show the relation of the first two.

Table No. 16

COMPARISON OF THE FAHRENHEIT AND CENTIGRADE THERMOMETRIC SCALES.

F	C	F	C
−459.6	−273.1111	190.0	87.7778
− 20.0	− 28.8889	200.0	93.3333
− 10.0	− 23.3333	210.0	98.8889
0.0	− 17.7778	Boiling Point 212.0	100.0000
+ 10.0	− 12.2222	220	104.4444
20.0	− 6.6667	230	110.0000
30.0	− 1.1111	240	115.5555
Freezing Point 32.0	0.0	250	121.1111
40.0	+ 4.4444	260	126.6667
50.0	10.0000	270	132.2222
60.0	15.5555	280	137.7778
70.0	21.1111	290	143.3333
80.0	26.6667	300	148.8889
90.0	32.2222	310	154.4444
100.0	37.7778	320	160.0000
110.0	43.3333	330	165.5555
120.0	48.8889	340	171.1111
130.0	54.4444	350	176.6667
140.0	60.0000	360	182.2222
150.0	65.5555	370	187.7778
160.0	71.1111	380	193.3333
170.0	76.6667	390	198.8889
180.0	82.2222	400	204.4444

Table No. 17

COMPARISON OF THE CENTIGRADE AND FAHRENHEIT THERMOMETRIC SCALES.

C	F	C	F
−273.1	356.0	190.0	374.0
− 20.0	−459.6	200.0	392.0
− 10.0	− 4.0	210.0	410.0
0.0	+ 14.0	220.0	428.0
+ 10.0	32.0	230.0	446.0
20.0	50.0	240.0	464.0
30.0	68.0	250.0	482.0
40.0	86.0	260.0	500.0
50.0	104.0	270.0	518.0
60.0	122.0	280.0	536.0
70.0	140.0	290.0	554.0
80.0	158.0	300.0	572.0
90.0	176.0	310.0	590.0
100.0	194.0	320.0	608.0
110.0	212.0	330.0	626.0
120.0	230.0	340.0	644.0
130.0	248.0	350.0	662.0
140.0	266.0	360.0	680.0
150.0	284.0	370.0	698.0
160.0	302.0	380.0	716.0
170.0	320.0	390.0	734.0
180.0	338.0	400.0	752.0

FORMULAE FOR REDUCING FROM ONE THERMOMETRIC SCALE TO ANY OTHER.

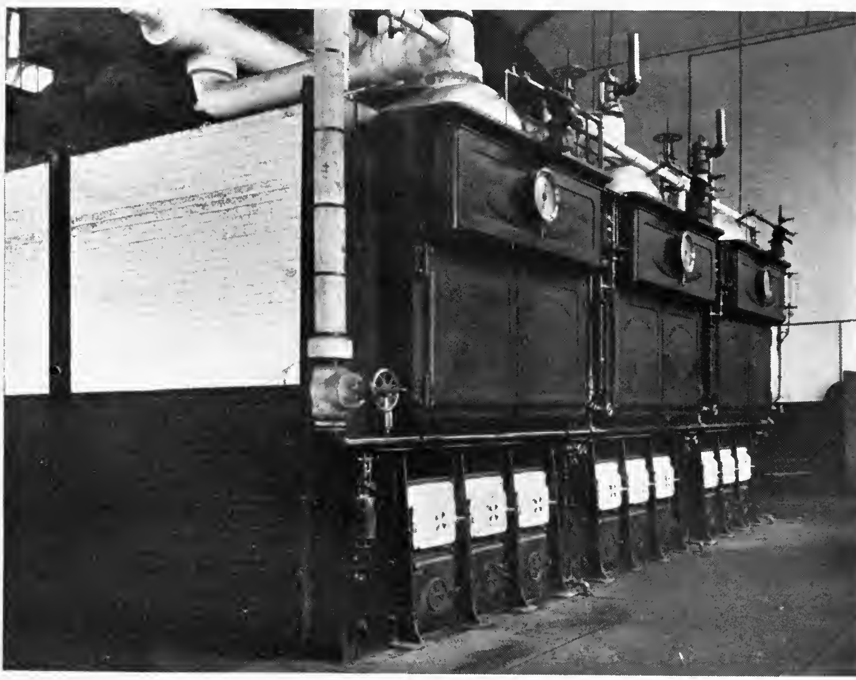
$F = \frac{9}{5}\,C + 32^\circ \quad = \frac{9}{4}R + 32^\circ$ F = degrees Fahrenheit

$C = \frac{5}{9}\,(F - 32^\circ) = \frac{5}{4}R$ C = " Centigrade

$R = \frac{4}{5}\,C \quad = \frac{4}{9}(F - 32^\circ)$ R = " Reaumer

PRACTICAL PYROMETRY.

"Many scales for the measurement of high temperatures have been proposed, but the gas scale is the one now universally adopted. All readings obtained by any type of heat measuring instruments are reduced to temperatures on the gas scale. The gas scale has been adopted as the standard scale of temperature, firstly, because gas of the same purity can be produced at any time; secondly, the expansion of gas, which defines the scale of temperature, is sufficiently fine for accurate measurement; thirdly, the scale is practically identical with the thermodynamic scale. The mercurial thermometer also conforms to this scale quite accurately.



ANSONIA BRASS AND COPPER CO. BRASS MILL, ANSONIA, CONN., THREE 250 H. P. HEINE BOILERS.

Thermometers and pyrometers are generally standardized by means of fixed points of fusion and ebullition determined by gas thermometers.

Following is a list of the high temperature measuring devices generally used, with a statement of their approximate limitations:

TYPES OF PYROMETERS IN GENERAL USE.

Thermometer	Character	Type	Range in degrees C over which they can be used.
Expansion	Those depending upon changes in volume or length by temperature.	Gas Mercury, Jena glass and nitrogen Glass and spirit or petrol Unequal expansion of metal rods Contraction of porcelain.	0° to 1000° − 40° to 500° −200° to −40° 0° to 500° 0° to 1800°
Transpiration and Vicosity.	Those depending on the flow of gases through capillary tubes or small apertures.	The Uehling.	0° to 1000°
Thermo-electric.	Those depending on the electromotive force developed by the difference in temperature of two similar thermo-electric junctions opposed to one another.	Galvanometric Potentiometric	0° to 1600°
Electric resistance.	Those utilizing the increase in electric resistance of a wire by temperature.	Direct reading on Indicator or bridge of galvanometer.	0° to 1200°
Radiation	Those depending on heat radiated by hot bodies.	Thermo-couple in focus of mirror bolometer.	0° to 10,000°
Optical	Those utilizing the change in the brightness or in the wave length of the light emitted by an incandescent body.	Photometric comparison Incandescent filament in telescope. Nickel and quartz plate and analyzer.	0° to 2000°
Calorimeter	Those depending on the specific heat of a body raised to a high temp.	Copper or platinum ball with water vessel.	0° to 1500°
Fusion.	Those depending upon the unequal fusibility of various metals or earthern-ware blocks of various composition.	Alloys of various fusibilities.	0° to 1988°

The color of many highly heated substances is some indication of the temperature, but results obtained by this method are unsatisfactory except for rough estimation, as the susceptibility of the observer's eye

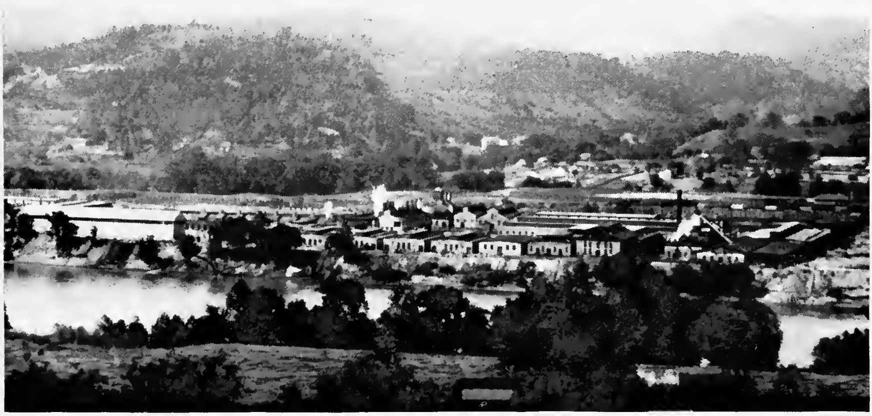
and the surrounding illumination are sources of considerable error. Table No. 18 gives a schedule for judging temperatures in this way.

Table No. 18

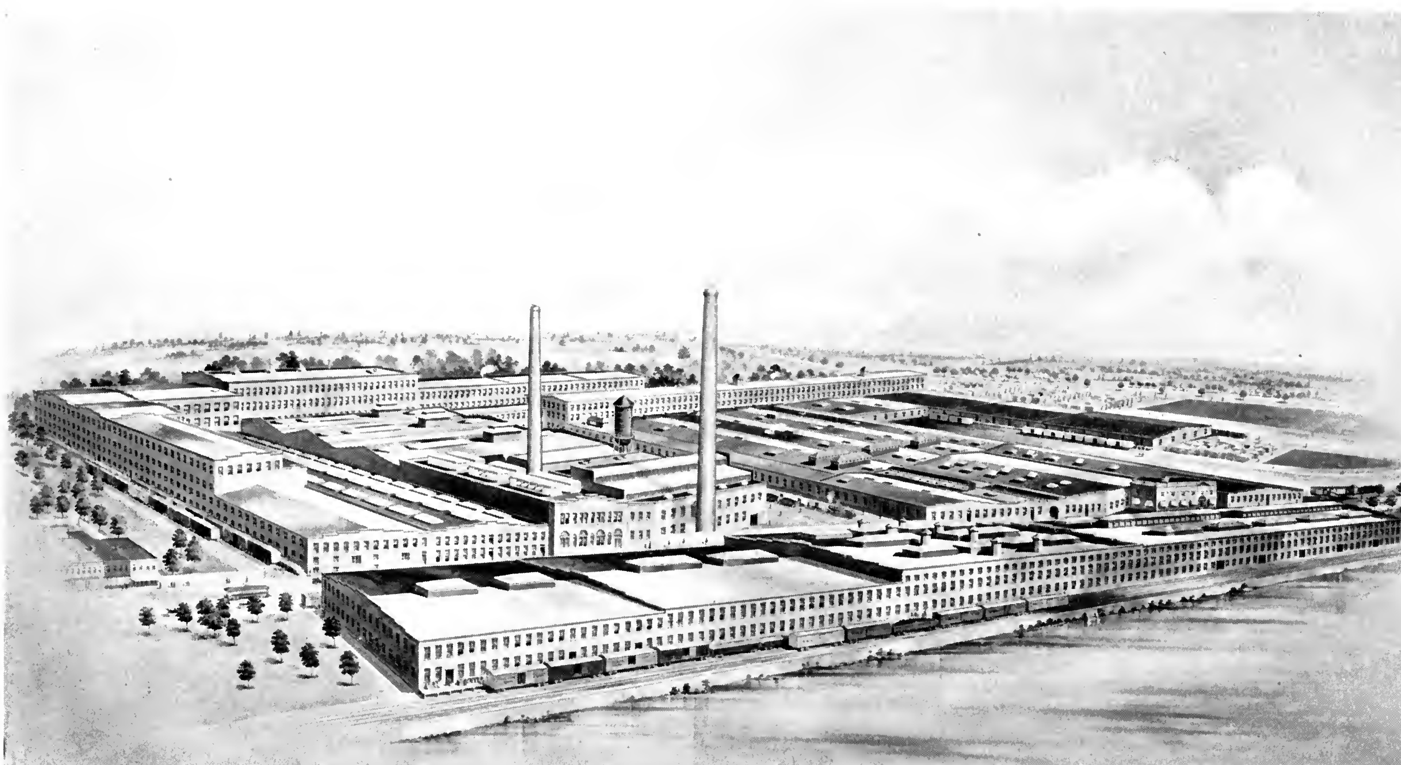
POUILLET COLOR SCHEDULE.

Appearance	C	F
Incipient red heat	525°	977°
Dull " "	700°	1292°
Incipient red cherry heat	800°	1472°
Red cherry heat	900°	1652°
Clear red cherry heat	1000°	1832°
Deep orange heat	1100°	2012°
Clear " "	1200°	2192°
White " "	1300°	2372°
Bright white heat	1400°	2452°
Dazzling	1500° 1600°	2732° 2912°

The comparatively recent development and perfection of the various heat measuring devices employing thermo-couples and of the radiation thermometers, has resulted in considerable changes in what have heretofore been considered the true temperatures of many metallurgical processes, which are now found to take place at lower temperatures than have long been considered accurate. A continued use of these more reliable means will inevitably result in the remodeling of the various tables which have been published and accepted for many years, giving the melting points of various metals and alloys.



KELLY AXE MFG. CO., CHARLESTON, W. VA.
CONTAINS, 2400 H. P. OF HEINE BOILERS.



CHAMPION COATED PAPER CO., HAMILTON, O., CONTAINS 3850 H. P. OF HEINE BOILERS.

COMBUSTION.

THE commonly accepted use of the word combustion refers simply to a process of burning, whereby any material or any part of it unites with the oxygen of the air, with the accompaniment of either light or heat or both. To speak of a substance therefore as a combustible means that it is susceptible of rapidly combining with oxygen so as to produce either light or heat or both, while the oxygen of the air may be classed as a supporter of such combustion.

Carbon—Carbon is one of the most widely distributed and easily obtained of any of nature's combustible substances, and it is because of its abundance and presence in coal, wood, peat, mineral oil and natural gases that these substances are used almost exclusively as fuel. Carbon itself is a non-volatile solid substance and exists in three distinct and apparently different states; first, as it is found in the diamond, second, in the shape of plumbago or graphite and third, as charcoal or lamp black. Among natural fuels, anthracite coal is almost pure carbon, and may be classed as between charcoal and graphite.

Hydrogen—Hydrogen is a light, colorless gas, the lightest of all known substances being about one sixteenth as heavy as oxygen. Its specific gravity is .0692, it weighs .0895 ounces per cubic foot, and one pound will occupy 178.83 cubic feet at 32°F. and under a pressure of one atmosphere.

Oxygen—Oxygen which we have described above as being the supporter of combustion, while one of the most common of all natural substances, is never found by itself in nature; in atmospheric air it is associated with the gas nitrogen, and in water oxygen exists in combination with hydrogen. Air is normally composed of oxygen and nitrogen in the following proportions:

By volume,	Oxygen................	0.213 parts
	Nitrogen..............	0.787 parts
and by weight,	Oxygen................	0.236 parts
	Nitrogen..............	0.764 parts

However, the above proportions are disturbed when vapor, carbonic acid and other impurities are present. Unless accuracy is desired it is usually correct enough to consider that atmospheric air is composed of one volume of oxygen and four volumes of nitrogen. The combination of oxygen and nitrogen as air is merely a mechanical mixture of the two and the oxygen is therefore free to leave the nitrogen at any moment, combine with any other substance with which it may be in contact and

for which it has an affinity and if the conditions are favorable this combining process may take place with great speed and vigor. When isolated, oxygen is a colorless gas, tasteless and slightly heavier than air, its specific gravity being 1.1056, air being 1.00; its weight per cubic foot is 1.428 ounces, and one pound will occupy 11.205 cubic feet at 32°F. under a pressure of one atmosphere.

THE ATOMIC THEORY.

In order to obtain a clear comprehension of the varied and numerous chemical changes involved in the phenomena of combustion it is desirable to have some knowledge of the atomic theory.

This theory is the one generally accepted as governing all chemical combinations and has been developed through experiments and investigations extending over very many years.

It has been found that when two elementary substances combine chemically they do so in a definite and invariable proportion. For instance if oxygen and hydrogen are mixed and caused to form water they will so combine only in the exact proportion of two volumes of hydrogen for each volume of oxygen. Two volumes of hydrogen cannot be made to combine chemically with one and one-half volumes of oxygen to form the compound water, but the hydrogen will combine only with its proportionate quantity of oxygen, leaving the extra one-half volume entirely undisturbed.

Experiment has also proven that after two volumes of hydrogen have combined with one volume of oxygen and if the temperature is such as to retain the resultant compound water in its gaseous state it will occupy only the space of two volumes, although three volumes of the gases have been used in its production. We may reasonably suppose therefore that if the smallest conceivable particle of oxygen be caused to unite with two of the smallest particles of hydrogen the same result will follow and a very minute particle of water will be formed. These minute particles, the smallest in which substances may be conceived to enter into combination with each other, are called atoms and the individual particles resulting from the combination are known as molecules. It is therefore reasoned that equal volumes of the elementary gases contain the same number of atoms, and that therefore these atoms are of equal size.

Alphabetical characters or letters, usually the initial letter of the name, have been adopted as designating symbols for the various elements, followed when necessary for distinction, by other letters. Thus hydrogen is designated by the capital letter "H" and oxygen by the cap-

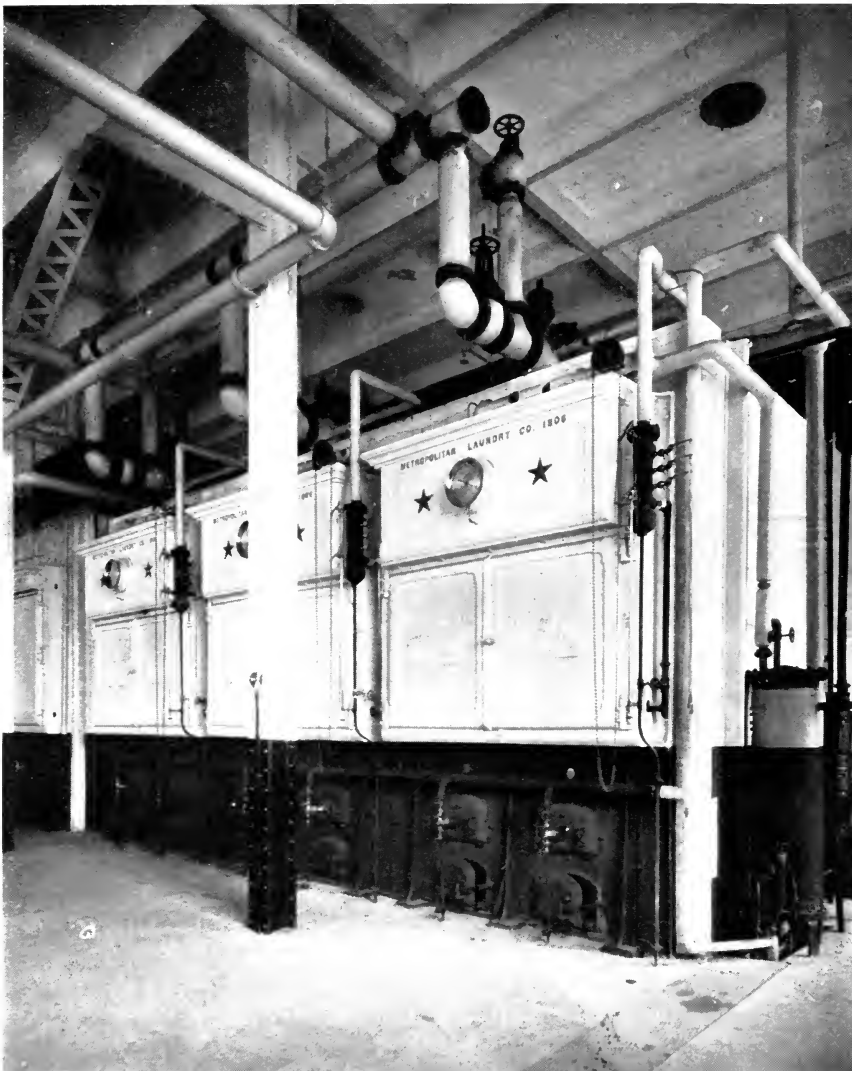
ital letter "O". Water therefore being a chemical union of two atoms of hydrogen and one atom of oxygen is always represented as H_2O. The suffix 2 being employed to state the fact that there is twice as much hydrogen, by volume, as there is oxygen.

Having assumed as above stated that the atoms of all elementary substances are of the same size, the determination of the relative weights of equal volumes of the two gases is equivalent to determining the relative weights of the atoms themselves; that is, their atomic weights. Hydrogen being the lightest of all known substances its weight is taken as unity, the relative weight of oxygen being 16, that is any given volume of oxygen weighs 16 times as much as an equal volume of hydrogen. We therefore find the further fact as to the composition of water, that two atoms of hydrogen weighing $2 \times 1 = 2$, combine with one atom of oxygen weighing 16. In other words, by weight, water is composed of two parts of hydrogen and 16 parts of oxygen, or that combination is in the ratio of one hydrogen to eight oxygen. We have already shown that the two volumes of hydrogen and one volume of oxygen when united occupy only two volumes, which is the same as was occupied originally by the hydrogen, hence the compound now weighing eighteen occupies the same space as the original amount of hydrogen weighing two, and its relative density is therefore, $\frac{18}{2} = 9$, or gaseous water of given temperature and pressure weighs nine times as much as an equal volume of hydrogen under the same conditions.

We give below a table showing the symbols and atomic weights of several of the common elementary substances.

Hydrogen	H	1
Carbon	C	12
Nitrogen	N	14
Oxygen	O	16
Sulphur	S	32

Combination of Carbon and Oxygen—A few of the elements may combine chemically with each other in more than one proportion. This is true of carbon and oxygen; for instance a quantity of carbon heated to incandescence and placed in a sufficient volume of oxygen will unite with it, each atom of carbon combining with two atoms of oxygen forming a compound formerly known as carbonic acid, but now universally termed carbon dioxide, the symbol of which is CO_2. The process is indicated by the formula $C + 2O = CO_2$, and no matter how large the supply of oxygen may be it cannot be made to combine with a greater proportion of carbon. Therefore this gas, carbon dioxide, is evidently the product of complete combustion, there having been present a surplus



THREE 350 H. P. HEINE BOILERS, BURNING FUEL OIL,
METROPOLITAN LAUNDRY, SAN FRANCISCO.

of oxygen. As shown by the list above, a single atom of carbon weighs 12, and a single atom of oxygen weighs 16, therefore the compound, carbon dioxide, consists of, by weight, 12 parts of carbon and $2 \times 16 = 32$ parts of oxygen.

Carbon dioxide gas is transparent and colorless; its specific gravity 1.529, being about one and one-half times heavier than air. It has a slightly acid taste and smell and being the product of complete combustion is of course incombustible. It is therefore neither a supporter of animal life nor of combustion, although it is not directly poisonous.

If, however, this carbon dioxide gas without the presence of sufficient oxygen is brought into contact with more carbon heated to incandescence it will give up one half of its oxygen, each atom of which being released at once unites with an atom of carbon from the second mass, forming a new compound known as carbon monoxide, of which gas the symbol is CO. The process is symbolically expressed as follows: $CO_2 + C = 2CO$, showing that not only is the new compound formed by the carbon with the released oxygen, but that the carbon dioxide being deprived of part of its oxygen is thereby also reduced to carbon monoxide. The relative weight of this combination is evidently $12 + 16 = 28$.

Carbon monoxide gas has a specific gravity of 0.9674, being slightly lighter than air. It is transparent, colorless, and almost without odor, is destructive to animal life, being a direct poison. It is not a supporter of combustion, but being already the product of imperfect combustion, it is in itself a combustible, and may be readily burned in air. This can be demonstrated by experiment and the product will be found to be carbon dioxide identically the same compound already shown to be the result of complete combustion. Symbolically the process is expressed thus, $CO + O = CO_2$.

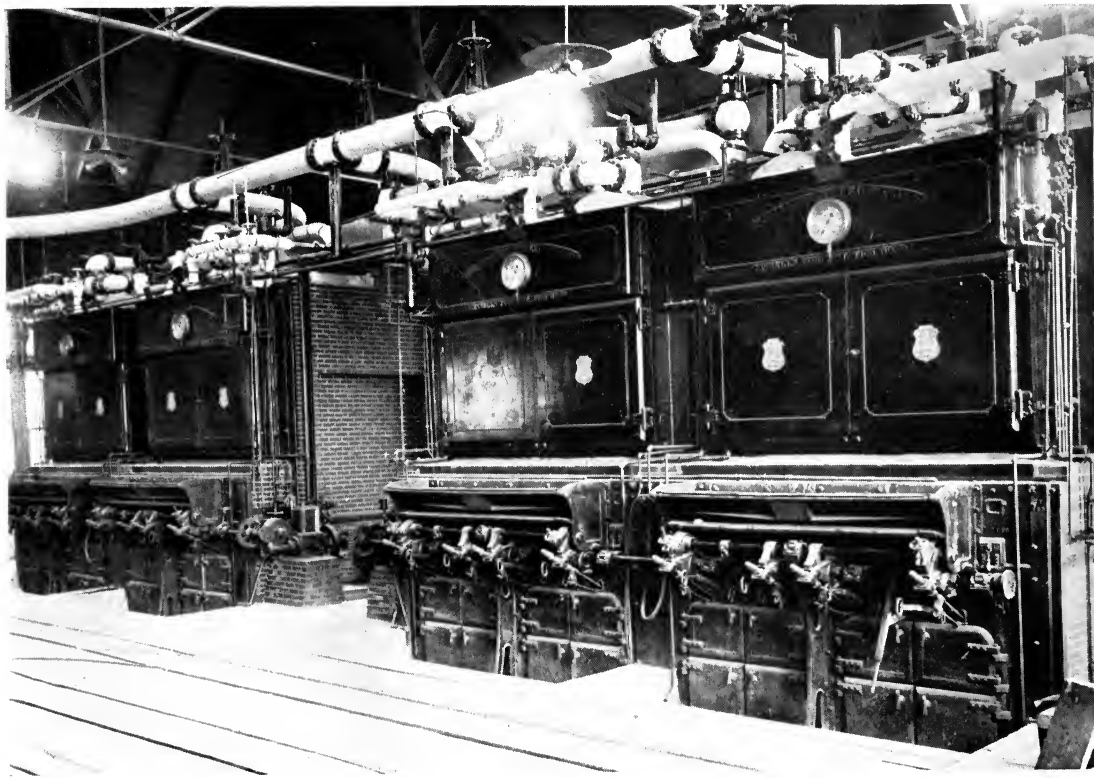
Table No. 19 shows the properties of the two gases.

Table No. 19

Name	Symbol	Carbon	Oxygen	Total	Percentage		Total
					Carbon	Oxygen	
Carbon Monoxide..	CO	12	16	28	42.86	57.14	100
Carbon Dioxide....	CO_2	12	32	44	27.27	72.73	100

THE BURNING OF FUEL.

The two elements which contribute most largely to the heat value of any fuel are the carbon and the hydrogen. These two may be either



FOUR 350 H. P. HEINE BOILERS, ST. LOUIS WATER WORKS, EQUIPPED WITH RONEY STOKERS.

combined in the fuel naturally or when heat is applied associate themselves together in a number of complex compounds called hydro-carbons.

These compounds are very numerous, the simplest of them all being what is commonly known as marsh gas, the symbol for which is CH_4. Such of the carbon or hydrogen as does not thus enter into combination is designated as fixed.

Besides these more valuable constituents, fuels usually also contain small amounts of oxygen, sulphur and nitrogen, together with some incombustible matter, such as minerals or earthy matters, which remain as ash. The process of the combustion of ordinary fuel is therefore a much more complex operation than the combustion of carbon alone, which we have just described.

Table No. 23 (page 49) gives the average relative composition by weight of a number of fuels, as determined by analysis. For the general purposes of comparison of different fuels the proximate analysis giving only the relative percentages of fixed carbon, volatile matter, moisture and ash, is sufficiently close.

We can no more than outline the actual process of combustion of any fuel as the conditions under which the burning takes place make it absolutely impossible to state the actual order in which the various processes occur.

If, for instance, bituminous coal is thrown upon a glowing fire composed of incandescent carbon, the heat will volatilize and free the hydrocarbons at comparatively low temperatures and these inflammable gases are immediately burned and by their heat assist in bringing the balance of the coal up to the temperature of incandescence. During the burning of the hydro-carbon gases the various combinations are broken up and simpler combinations are formed. If there is sufficient oxygen present the carbon unites with it and forms carbon dioxide, the hydrogen also unites with oxygen and forms water in a gaseous state. Now, if a portion of the carbon which has been liberated in the shape of incandescent particles from the hydro-carbon gases does not at once meet with sufficient oxygen, it is liable to cool so that if it subsequently does meet with oxygen its temperature may be too low to permit of their chemical combination. It will therefore pass off still unconsumed and visible in the form of smoke. By the time all of the hydro-carbons have been expelled from the coal and either burned or driven off unconsumed, the remainder of the coal will have become heated to incandescence and the carbon in it will then readily combine, either with the oxygen from the air or with carbon dioxide which may be present. If plenty of oxygen is present the product of the union will be carbon dioxide. If however, there is insufficient oxygen

EIGHT 445 H. P. HEINE BOILERS, CHINO COPPER CO., HURLEY, N. MEX., IN PROCESS OF ERECTION WITH HEINE SUPERHEATERS.

or air present, the incandescent carbon will seize upon part of the oxygen in the carbon dioxide gas present with a resultant of carbon monoxide gas, or incomplete combustion. If the gas thus formed should subsequently be brought into contact with air it would take therefrom oxygen and burn to carbon dioxide, provided the temperature is sufficiently high.

HEAT OF COMBUSTION.

Table No. 20 shows the heat of combustion, in oxygen, of one pound of each of the substances named, in British Thermal Units. It also shows the weight of oxygen required to combine with each pound of combustible and the weight of air necessary to supply that oxygen.

Table No. 20

	Pounds Oxygen	Pounds Air	British Thermal Units.	Theoretical Evaporation f. & at 212°F.
Hydrogen Gas..............	8	36	62,032	64.2
Carbon imperfectly burned into Carbon Monoxide...	1.33	6	4,400	4.55
Carbon perfectly burned into Carbon Dioxide.....	2.66	12	14,500	15.00
Olefiant Gas..............	3.43	15.43	21,344	22.1
Various Liquid Hydro Carbons....................			From 21,700 to 19,000	From 22.5 to 20.0
Carbon Monoxide.........	0.643	2.571	4,286	4.48

Note that the imperfect burning of carbon into carbon monoxide yields less than one third the heat it would had it burned completely into carbon dioxide. Here undoubtedly occurs the greatest furnace loss rather than in the smoke, and indeed the chimney may be perfectly clean and unobjectionable. An analysis from a boiler whose chimney is belching forth intensely black smoke may show a minimum of carbon monoxide and maximum of carbon dioxide, the loss being merely that due to the incomplete combustion of a very small percentage of solid carbon carried off with the gases.

The total heat of combustion from any hydrogen and carbon compound is considered to be the sum of the heat quantities which the individual constituents would produce if burned separately.

When hydrogen and carbon exist in a compound in the proportion, by weight, of one part of hydrogen to eight parts of oxygen the combination in combustion may be neglected in any calculation made to obtain

the total heat generated. When, however, hydrogen exists in a greater proportion than above stated the surplus not combining with the oxygen must be taken into account.

Dulong's formula for obtaining the total heat generated by one pound of fuel was used as determined originally for many years but the A. S. M. E. after an exhaustive discussion and investigation decided upon a modified Dulong formula as below.

$$H=14600C+62000\ (H-\frac{0}{8}) + 4000S.$$

When one considers the conditions actually existing in any fire, the varying sizes of the coal, the number and variety of empty spaces between them and the various stages of combustion at different parts of the fire, it is evident that very many great changes must take place in the composition of the gases, and that association and dissociation must follow each other very rapidly. A particle of carbon may first burn to carbon dioxide, meet another particle of carbon and part with one half of its oxygen becoming carbon monoxide and again meet with a further supply of oxygen and become again carbon dioxide. The combination in which the carbon and oxygen finally leave the furnace is dependent upon the temperature, quantity and places at which the oxygen is admitted. The operation of burning coal is therefore complex and the conditions actually existing in any furnace must govern the manner in which that furnace must be operated to secure complete combustion.

QUANTITY OF AIR REQUIRED FOR COMBUSTION.

The symbol for water is H_2O and the atomic weights are $H=1$ and $O=16$, therefore $H_2O=2+16$ and $H_2:O::2:16=H_2:O::1:8$, therefore one pound of hydrogen requires eight pounds of oxygen for its complete combustion.

Likewise the symbol of carbon dioxide is CO_2, substituting the atomic weights we have $CO_2=12+(2\times16)$ and therefore $C:O_2::1:2\frac{2}{3}$; hence one pound of carbon requires $2\frac{2}{3}$ pounds of oxygen for its complete combustion. On page 29 we have shown that by weight one pound of atmospheric air contains 0.236 parts of oxygen, therefore it is evident that for the combustion of one pound of carbon we must have such an amount of air as will contain $2\frac{2}{3}$ pounds of oxygen. That is $2\frac{2}{3}\div 0.236 = 11.3$ pounds of air. Similarly with the hydrogen $8.0 \div 0.236 = 33.9$. Table No. 21 gives data as to oxygen, and the common combustibles, together with the pounds and cubic feet of air required for each, calculated in the manner just described.

Table No. 21.

COMBUSTION DATA.

Combustible	Atomic Weight	Combustion Product	Wt. of O. per lb. of Combustible	Am't. of air consumed per lb. of combustible		Calorific Power. Heat units per lb. of Combustible
	H=1		Lbs.	Lbs.	Cu. Ft. 62° F.	B. T. U.
Oxygen (O).....	16	....	....	....	....	....
Hydrogen.......	1	Water (H_2O)..	8.0	34.8	457	62032
Carbon (C).....	12	Carbon Monoxide (C O)..	1.33	5.8	76	4452
Carbon (C).....	12	Carbon Dioxide (CO_2).	2.66	11.6	152	14500
Carbon Monoxide (C O).........	28	Carbon Dioxide (CO_2).	0.57	2.48	33	4325
Marsh Gas (CH_4)	16	CO_2 & H_2O...	4.00	17.4	229	26383
Olefiant Gas (C_2H_4)..........	28	CO_2 & H_2O. .	3.43	15.0	196	21290
Sulphur (S).....	32	SO_2.........	1.00	4.35	57	4032

For insuring completeness of combustion, the first condition is a sufficient supply of air; the next is that the air and the fuel, solid and gaseous, shall be thoroughly mixed; and the third is that the elements—air and combustible gases—shall be brought together and maintained at a sufficiently high temperature. The hotter the elements the greater is the probability of good combustion.

Dulong's formula for the weight of air required for the combustion of any fuel whose chemical composition is known is:

$$W = 11.61C + 34.78\ (H - \frac{0}{8}), \text{ or approximately}$$

$$W = 12\ C + 35\ (H - \frac{0}{8})$$

Where C, H and O represent the weight of carbon, hydrogen, and oxygen in the fuel and W equals the weight of air required.

The volume (V) of air required is given by Dulong as:

$$V = 152.56\ C + 457.04\ (H - \frac{0}{8}), \text{ or approximately}$$

$$V = 1.53 + C\ 457\ (H - \frac{0}{8})$$

Theoretically 12 pounds of air are sufficient for the complete combustion of one pound of good coal but usually considerably more air than this is admitted, 24 pounds of air per pound of coal being not uncommon with natural draft. With artificial draft the amount may be only 50

U. S. REALTY BLDG., NEW YORK, N. Y.,
CONTAINS 1,525 H. P. OF HEINE BOILERS.

per cent in excess of the chemical requirements. Table No 22 gives some data regarding the relation between the temperature and volume of gases of combustion.

Table No. 22.

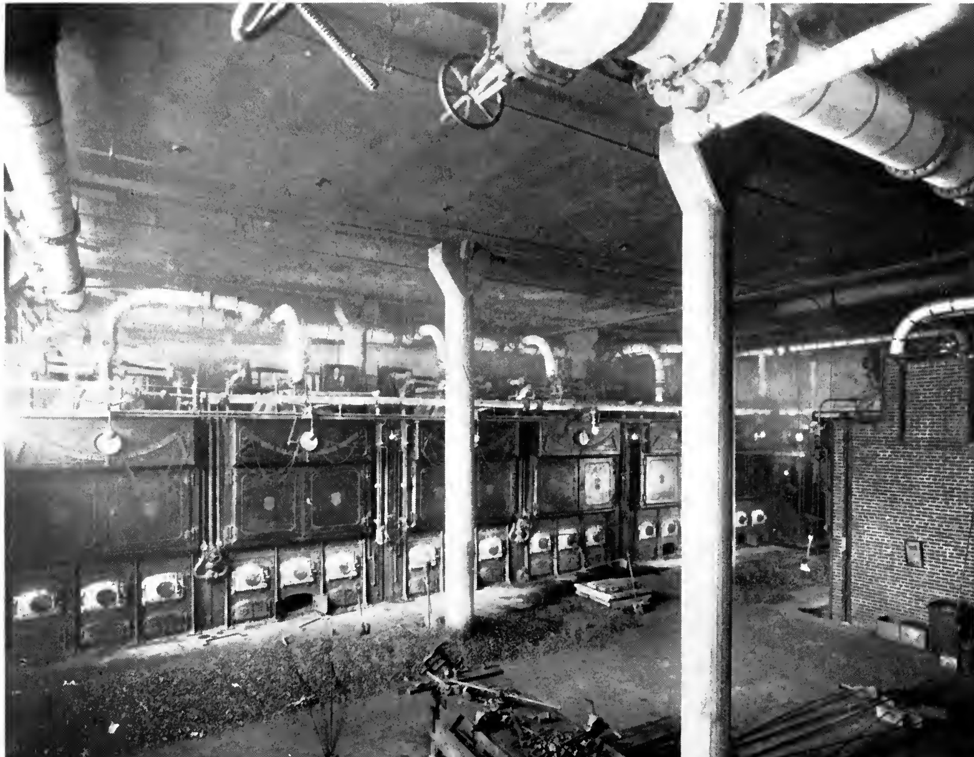
TEMPERATURE OF COMBUSTION AND VOLUME OF PRODUCTS.

Temperature of Gas, Fahrenheit	Supply of air in lbs. per lb. of fuel		
	12 lbs.	18 lbs.	24 lbs.
	Volume of air or gases in cu. ft. at each temperature.		
32	150	225	300
68	161	241	322
104	172	258	344
212	205	307	409
392	259	389	519
572	314	471	628
752	369	553	738
1112	479	718	957
1472	588	882	1176
1832	697	1046	1395
2500	906	1359	1812
3275	1136	1704	....
4640	1551	....	....

This table shows the volume, at different temperatures, of the air required (1) when just enough is admitted to burn C to CO_2, (2) with 50% excess, (3) with 100% excess. The table also shows the volume of gases of combustion at various temperatures. From this data may be figured the proper areas for different purposes, such as ash pit doors, breechings, etc.

The ample dimensions of the combustion chamber, which is an important feature of the setting of a Heine Boiler under any conditions and for all types of furnaces and stokers, meets those theoretical and practical requirements necessary for the attainment of the best combustion of all kinds of fuels; but preeminently of the long flaming solid fuels and of the gaseous or liquid fuels. It is practicable to install, at the lowest cost, any special furnace arrangement desired. On pages 167, 168, 169 may be found some illustrations suggesting methods of applying various types of furnaces.

When oil or gas is to be used any arrangement of baffle walls, checker work, air preheating ducts, etc., can be easily installed. The convenience with which changes can be made offer the investigating engineer opportunity to make experiments and changes very cheaply.



EIGHT 316 H. P. HEINE BOILERS, VICTOR TALKING MACHINE CO., CAMDEN, N. J. EQUIPPED WITH HEINE SUPERHEATERS.

FUELS.

THE various substances which are used for the generation of heat may be divided as follows:

Solids	Coal Coke Peat Tar Wood Tanbark Straw Bagasse

Liquids of the petroleum group.

Gases	Natural Gas Producer Gas.

By far the most common and important fuel in use is coal in its various stages of development.

The use of wood as a fuel is restricted to special and peculiar processes as the necessary and increasing demand for its use for structural and other industrial purposes has nearly removed it from any consideration as a fuel.

Special processes and favorable local conditions are necessary before any competition between either fuel oil or of gases and coal can exist.

COAL.

Coal is a dark brown or black mineral substance varying in specific gravity from 1.2 to 1.8. It burns with a more or less brilliant formation and unless under favorable circumstances its combustion is likely to be attended with considerable smoke. Coal is found in horizontal or in inclined layers, being separated by seams of clay and frequently mixed with iron compounds. It is found in that geological formation commonly known as the carboniferous and it generally lies between primary formations called Silurian on one hand and the sand stone on the other. Anthracite which is the oldest variety in a geological sense, is sometimes found among the most recent members of the transition formations, while lignite or brown coal the youngest variety occurs in the chalk formation.

NEW ORLEANS SEWERAGE AND WATER BOARD SEWERAGE STATION A. CONTAINS 1000 H. P. OF HEINE BOILERS.

All coals are composed of the same chemical constituents, viz.: hydrogen, carbon and oxygen, and it is the varying quantities of each and their combinations, which cause the differing values of the several coals as heat producers.

All coals are formed from prehistoric vegetable growths, fossilized by moisture, heat, pressure and time. The chemical and structural changes which have taken place therefrom, may be roughly stated as follows:

Substance	Carbon	Hydrogen	Oxygen
Wood Fibre	52–53%	5–55%	40–42%
Peat	58–60%	55–60%	40–42%
Lignite	60–62%	50–55%	34–35%
Brown Coal	65–70%	50–55%	25–30%
Bituminous Coal	70–85%	55–60%	18–20%
Anthracite Coal	85–92%	4–57%	4–4½%

In addition to the above evidence as to the vegetable origin of coal, fossilized trees are found standing upright and with their roots resting in the seams of coal, also ferns, leaves, boughs, etc., either wholly or partially fossilized are found in peat bogs.

It is stated that several hundred different species of plant life have been identified in and among coal formations. It is an interesting fact that these evidences found in the coal measures, by the comparison with existing forms of plant life, testify to the fact that the climate now existing at those points is materially changed from that which existed at the time of their growth. All such specimens which have been found indicate that their natural habitat was in a very warm moist climate, and that after falling they were subjected to various changes of location due to internal disturbances of the earth, at times being buried under the water, and at other times, probably by volcanic action, elevated high above the water.

These deposits vary considerably in age, and distinct species exist which may be distinguished from one another as well by the physical structure as by the chemical peculiarities. The coal which occurs above the chalk formation is of comparatively recent origin. This is lignite or brown coal, which frequently contains almost the entire structure of the vegetable matter from which it was formed. That lying below the chalk is known as bituminous coal and in it the vegetable feature has disappeared excepting in isolated cases. Both differ from the anthracite or oldest coal, from which almost everything has disappeared excepting the carbon.

Coals are roughly divided into classes or groups about as follows:

Anthracite
Semi-Anthracite
Semi-Bituminous
Bituminous
Lignite

These approximate distinctions, however, so merge into each other, that it is at times difficult to designate a class to which a particular coal may be assigned, and for this reason many attempts have been made to scientifically group or class them. These classifications have been based upon the preponderance of certain fuel elements in the different coals but without success, as the attempt has always resulted in some one or two glaring discrepancies.

The U. S. G. S. however has gone into the matter of proper grouping or classification of coals very exhaustively. In their report on the Coal Testing Plant at St. Louis, "Professional Paper No. 48, Part One," using various elements and ratios, they find that the carbon hydrogen ratio $\frac{C}{H}$, while not ideally perfect, seems to fit the cases better than any others, and suggest for investigation and discussion the following groups, arbitrarily designated by letters.

Group	A	(Graphite)	∞ to (?)
"	B	Anthracite	(?) to 30 (?)
"	C	"	30 (?) to 26 (?)
"	D	Semi-Anthracite	26 (?) to 23 (?)
"	E	" Bituminous	23 (?) to 20 (?)
"	F	Bituminous	20 to 17
"	G	"	17 to 14.4
"	H	"	14.4 to 12.5
"	I	"	12.5 to 11.2
"	J	Lignite	11.2 to 9.3 (?)
"	K	Peat	9.3 (?) to (?)
"	L	Wood	7.2

From this report we quote: "*Groups A, B, C, D, and E.* As little work was done at this testing plant on anthracite coal, and as all of the analyses made by the Second Geological Survey of Pennsylvania were proximate analyses, little material is available for determining the limits of these groups and the figures given must be regarded as provisional only, and subject to change when a greater number of ultimate analyses have been made.

Groups F, G, H, I. These groups embrace what generally are considered bituminous coals.

Group F. Includes Pocahontas coal, the high grade Arkansas coals west of the Spadra District and New River coals.

Group G. Includes upper Freeport and Pittsburg coals or Northern W. Virginia, Kanawha Valley coals, high grade Kentucky coals, and Alabama coals.

Group H. Includes all Indian Territory coals, all Kansas coals, high grade Illinois, Iowa and Missouri coals, and second grade Kentucky coals.

Group I. Includes the great majority of Iowa, Illinois, and Missouri coals, Indiana coal and some bituminous coals from Wyoming and Montana.

Group J. Includes all the lignites, both black and brown that were tested.

Group K. Is limited to peat and is based entirely upon one analysis obtained from outside sources.

Group L. Is woods, the lowest group in the series."

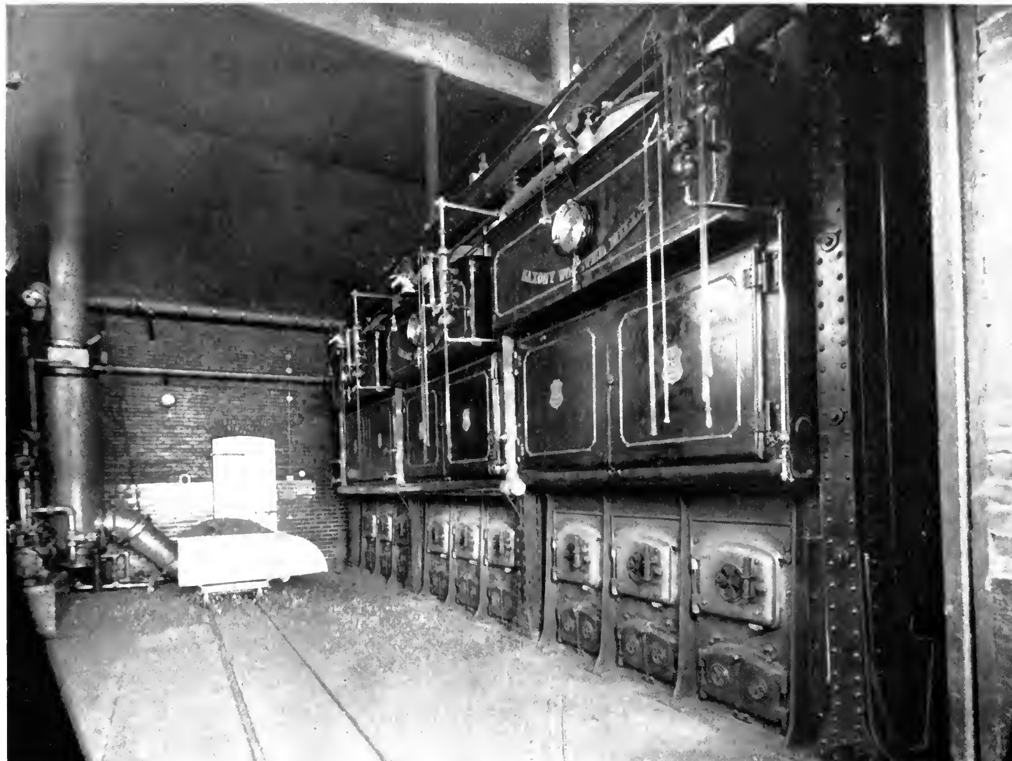
Coal from every district, indeed from different mines of the same region vary in their composition. Any table of analyses could therefore only be of very restricted use, since it is of course impracticable to publish a complete list. However, in order to give a general idea of the average characteristics of typical coals, table No. 23 has been compiled from the reports of the U. S. G. S. and represents a fair average of what may be expected of anthracite, semi-bituminous, bituminous and lignite coals of the U. S.

METHODS OF FIRING COAL.

There are three methods of charging coal known as the alternate, the spreading, and the coking systems.

The alternate system consists of charging the fresh coal alternately first on one side of the furnace and then on the other or in alternate doors where there are more than two. In this manner the gases that are given off from the freshly fired coal are burned by the hot excess air coming through the unfired portions of the furnace. This system is used to good advantage where the grates are very wide or where two or more furnaces have a common combustion chamber.

The spreading system consists in charging the coal in a thin layer over the entire grate at each firing, usually commencing at the bridge wall and working toward the door. This means that the furnace must be fired often and in small amounts, or in the fire room vernacular, "by the spoonful".



THREE 258 H. P. HEINE BOILERS, SAXONY WORSTED MILLS, NEWTON, MASS.

Table No. 23

COMPOSITION OF TYPICAL AMERICAN COALS.

U. S. GEOLOGICAL SURVEY.

	ANTHRACITE			SEMI-BITUMINOUS			BITUMINOUS					LIGNITES		
	Lehigh, Mine Run	Lykens Valley, Mine Run	Scranton, Culm	Pocahontas, Sewell, W. Va.	Fire Creek, W. Va.	Coalhill, Ark., Lump and Slack	Marion, Ill., Run of Mine	StraightCreek, Ky., Run of Mine	Bevier, Mo. Run of Mine	Hamilton, Iowa, Run of Mine	Fleming, Kan.	North Dakota, Brown Lignite	Texas, Brown Lignite	Wyoming, Black Lignite
Proximate analysis														
Moisture	1.97	1.50	2.08	1.90	3.24	1.28	5.96	1.92	9.14	4.25	3.74	16.72	10.66	17.69
Volatile matter	4.35	7.84	7.27	18.08	16.26	12.82	30.29	36.56	34.53	37.02	33.11	37.10	39.42	37.96
Fixed carbon	86.49	81.07	74.32	77.03	75.19	73.69	52.16	56.27	39.02	41.74	50.01	39.49	40.11	39.56
Ash	7.19	9.59	16.33	2.99	5.31	12.21	11.59	4.44	17.31	16.99	13.14	6.71	9.81	4.79
Sulphur	0.64	0.50	0.77	0.67	0.64	2.01	1.77	1.24	5.30	5.20	4.34	0.63	0.71	0.63
Ultimate analysis														
Carbon	85.66	83.20	75.21	85.87	82.05	77.29	67.30	78.31	56.25	60.36	68.22	55.16	57.31	58.41
Hydrogen	2.78	3.29	2.81	4.65	4.94	3.74	4.92	5.36	4.96	4.84	4.91	5.61	5.28	6.09
Nitrogen	0.77	0.95	0.80	1.19	1.43	1.39	1.43	1.85	0.99	1.46	1.09	0.91	0.71	1.09
Oxygen	2.87	2.45	4.08	4.63	5.63	3.36	12.99	8.80	15.19	11.15	8.30	30.98	25.83	28.99
Calorific value														
Calorimeter	......	......	12,472	15,345	14,391	13,381	12,103	14,319	10,451	11,182	12,404	9,491	9,904	10,355
Dulong's formula	13,963	13,954	12,395	15,039	14,627	13,406	11,907	14,081	10,294	11,129	12,492	9,128	9,634	10,048

NORTH DENVER HIGH SCHOOL, DENVER, COL., CONTAINS 420 H. P. OF HEINE BOILERS.

The coking system consists in charging the coal on the dead plate or at the front of the fire in order that the mass may become coked through, after which this is pushed back toward the bridge-wall and spread evenly over the grates to make room for the new charge. This is the system used with nearly all mechanical stokers.

Table No. 24

PRODUCTION OF COAL IN THE UNITED STATES FROM 1814 TO THE CLOSE OF 1909, IN SHORT TONS.

	Anthracite	Bituminous.	Total.	Value.
1814-1845	16,473,243	11,203,971	27,679,214	
1846-1855	51,948,337	31,469,490	83,417,827	
1856-1865	98,593,540	75,201,474	173,795,014	
1866-1875	198,436,722	220,988,382	419,425,104	
1876-1885	309,991,788	537,768,531	847,760,319	
1886-1895	486,784,754	1,099,313,887	1,586,098,641	$1,856,147,740
1896-1905	612,395,214	2,220,007,502	2,832,402,746	3,306,933,826
1906-1909	321,214,636	1,449,952,180	1,771,166,816	2,215,095,448

COKE.

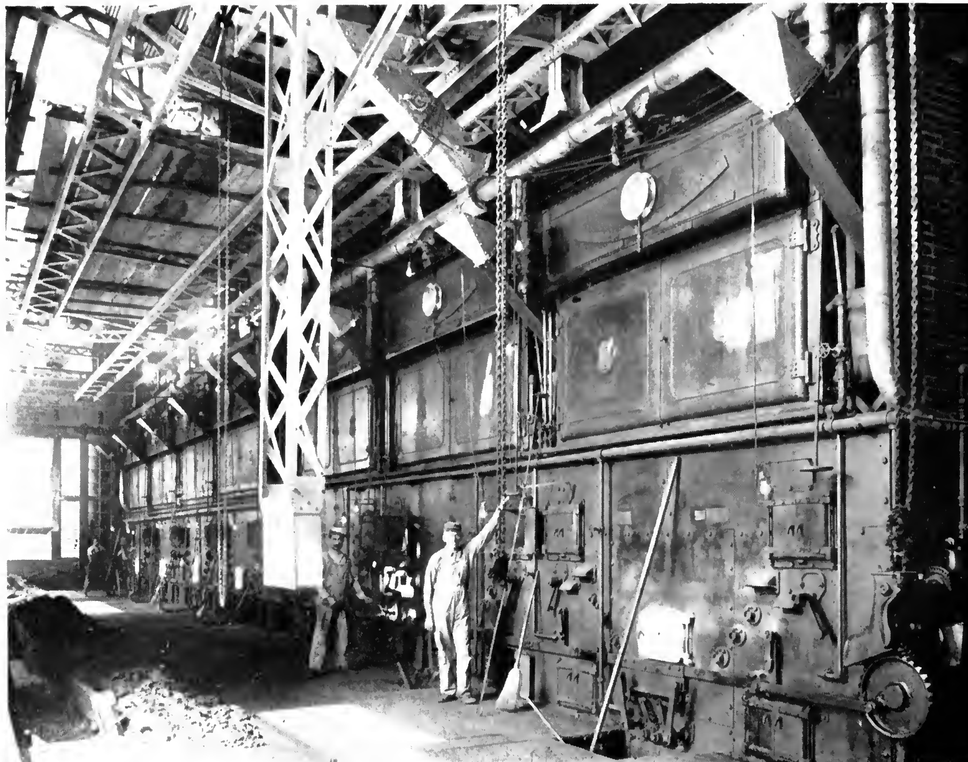
Coke is the solid substance remaining after the partial burning oi coal in an oven or after distillation in a retort.

When the former process is used, the coke is the primary product and any other products are considered as by-products being quite frequently thrown away, although modern coke making processes save most of them.

In the retort process, however, the coke itself is one of the by-products, the gases being the object of the operation, although the by-products have in later years become better revenue producers than the gas itself.

Gas retort coke is produced by the application of high temperature to the outside of the retort for a short time. The product is soft, spongy, and of dark grey color approaching black. It is not fitted for metallurgical work and its principal use is for domestic purposes, and in steam boiler practice.

Coke produced in beehive ovens however, is made under lower temperatures, the process requiring from 48 to 72 hours. It is hard, dense, and of a light grey color, has a brilliant metallic lustre, and will ring when struck. The product is especially adapted for heavy metallurgical work, but its high cost precludes its use for either steam boilers or do-



SEVEN 350 H. P. HEINE BOILERS, U. S. NAVY YARD, NORFOLK, VA.
EQUIPPED WITH MURPHY FURNACES.

mestic purposes. This same grade of coke is now extensively produced in closed ovens in a very much more economical way.

There is but little difference, as shown by chemical analysis, in the heating power of different cokes. It is roughly considered as being about 14000 B. T. U. per lb., and the difference in adaptability is due to the physical differences. Analyses of 29 samples of coke from six different states give averages as follows:

Carbon 89.15%, Sulphur 0.918%, Ash 9.21%.

The average weight of solid coke may be taken as 45 lbs. per cu. ft. The average weight of heaped coke may be taken as 30 lbs. per cu. ft. One long ton heaped averages 75 cu. ft.

Under ordinary conditions coke carries from 5% to 10% water, and if unprotected, will absorb from 15% to 25% of its own weight.

Good coal carefully handled in a beehive oven produces on an average of about 66% to 66½% coke, which can be marketed as such; about 2% to 2½% of breeze or fine coke and from 0.75% to 1% ash, there being an average of about 30% to 31% loss, mostly due to the volatile matters driven off in the coking process.

PEAT.

Peat is a substance of vegetable origin and is always found more or less saturated with water in swamps and bogs. It consists of roots and fibres in every stage of decomposition, from the natural wood to vegetable mold. It is valuable as a fuel only after having been dried out as much as possible. As found in the bog, peat usually contains 85% to 90% of water and when air dried still holds at least 15% moisture.

The analysis of air dried peat of good quality would be about as follows: 48% carbon, 4% hydrogen, 27% oxygen, 1% nitrogen, 15% moisture, 5% ash. 9000 B. T. U's.

The analysis of perfectly dried peat would be about as follows:

58% to 60% carbon, 6% hydrogen, 30% to 31% oxygen, 1% to 1½% nitrogen, 2¾% to 5% ash. 10260 B. T. U's.

The weight per cu. ft. peat heaped is from 6 lbs. to 22½ lbs., or 33.3 cu. ft. to 88.8 cu. ft. per ton of 2000 lbs.

Peat is prepared for use as fuel in three forms: First, as hand or spade peat; second, as briquetted peat; third, as machine peat.

(1) Spade peat is obtained by cutting out of the bog regularly shaped blocks, stacking the blocks on the ground to dry. The product is very commonly friable, will not stand transportation, is not suitable

SACRED HEART HOSPITAL, SPOKANE, WASH., CONTAINS 400 H. P. OF HEINE BOILERS.

for coking, and is usually quite bulky, although the specific gravity may run from 0.2 to 1.3.

(2) Briquetted peat is produced by compressing dry powdered peat with heavy machinery into regularly shaped blocks. The briquetted fuel is very clean and handsome, and bears transportation fairly well. Like the spade peat it is unsuitable for coking.

(3) The simplest and most practicable way of working the raw material into a satisfactory fuel, which is not bulky, which will stand transportation, and which is suited for coking is to make the so-called machine peat. The process is carried out with many different forms of machinery, all of which are dependent on the same principle; that when raw peat containing from 80% to 85% of water is thoroughly mixed and kneaded, it looses its fibrous structure and on drying shrinks firmly together into a compact mass of about one-fifth the original volume.

Machine peat, made from American material, ordinarily has a specific gravity of about 0.9, is tough enough to be cut like wood with a saw, and will take a moderate polish. It gives fine coke, containing no sulphur or phosphorous, and is especially fitted for replacing charcoal in metallurgical work.

Peat is found in many parts of Europe, and has been used in Ireland for many years as a domestic fuel. As a substitute for coal it is exciting considerable interest in this country, as large tracts have been discovered in Iowa, Wisconsin, N. Dakota and California, as well as at intervals along the eastern sea coast. The most valuable deposit so far discovered, exists in Minnesota, where hundreds of acres of peat, several feet deep, have been found.

While briquetted peat has been found to be a good fuel it has still greater possibilities in connection with gas engines. Compressed Florida peat produces a gas fully as valuable as that formed from lignites. The possibilities in this direction are so promising that the matter has been taken up by the governments of the United States and Canada in the hope and expectation of securing definite information.

TAR.

Coal Tar.

The value of coal tar as a fuel is usually very much lower than its value for other purposes, but it is at times used to advantage as a fuel. The yield of coal tar varies with the kind of coal and with the methods employed, from about 4½% to 6½% of the weight of coal. It is lower in

hydrogen and higher in carbon than crude oil, and therefore, of a lower calorific value. Tar made from standard gas coal would have an ultimate analysis about as follows:

Carbon	89.21%
Hydrogen	4.95%
Nitrogen	1.05%
Oxygen	4.23%
Sulphur	0.56%
Ash	Trace

It has a specific gravity of about 1.25; a gallon weighing 10.3 lbs.

Using Dulong's formula as adopted by the A. S. M. E., such fuel would have about 15800 B. T. U's. per lb., and a theoretical evaporative power of about 16.4 lbs. of water, from and at 212°F. A series of calorimetric tests give about 15700 B. T. U's. Coal tar may be burned if heated and strained, the same as other liquid fuels.

Oil Tar.

Oil tar is produced in an ordinary gas apparatus, has a specific gravity of 1.15, is less sticky than coal tar, and can be transported, handled and burned like other oils. Its analysis is about as follows:

Carbon	92.7 %
Hydrogen	6.13%
Nitrogen	0.11%
Oxygen	0.69%
Sulphur	0.37%
Ash	Trace

By the Dulong formula the above analysis would give 17296 B. T. U's., and its theoretical evaporative power would be about 17.9 lbs. of water from and at 212°F. By the calorimeter such oil gives a value of 17190 B. T. U's.

WOOD.

Wood may be described as vegetable fibre in its natural state. Usually the term is used to designate the limbs and trunks of trees as they are felled. Wood may be divided into two classes.

First, the hard, compact and comparatively heavy woods, such as oak, beech, elm and ash. Second, the light colored, soft, and comparatively light woods, such as pine, birch poplar and willow. When freshly

cut, about 45% of the total weight of wood is water, and when air dried and kept in a dry location, it still retains from 15% to 25% of water.

All woods have nearly the same heat value, as, when perfectly dry, all are practically of the same chemical composition. Thoroughly dried wood compared to coal is rated commonly as containing 0.40 the amount of heat contained in the same weight of coal, that is

1 lb. of wood = 0.40 lbs. coal
1 lb. of coal = 2.50 lbs. wood

The loss of economy due to the presence of water in the wood is shown in the following table, which gives the difference in chemical composition and heat value between perfectly dried wood and ordinary fire wood.

	Dry wood.	Ordinary fire wood.
Carbon	50%	37.5%
Hydrogen	6%	4.5%
Oxygen	41%	30.75%
Nitrogen	1%	0.75%
Ash	2%	1.50%
	100%	75.00%
Moisture		25.00%
		100.00%

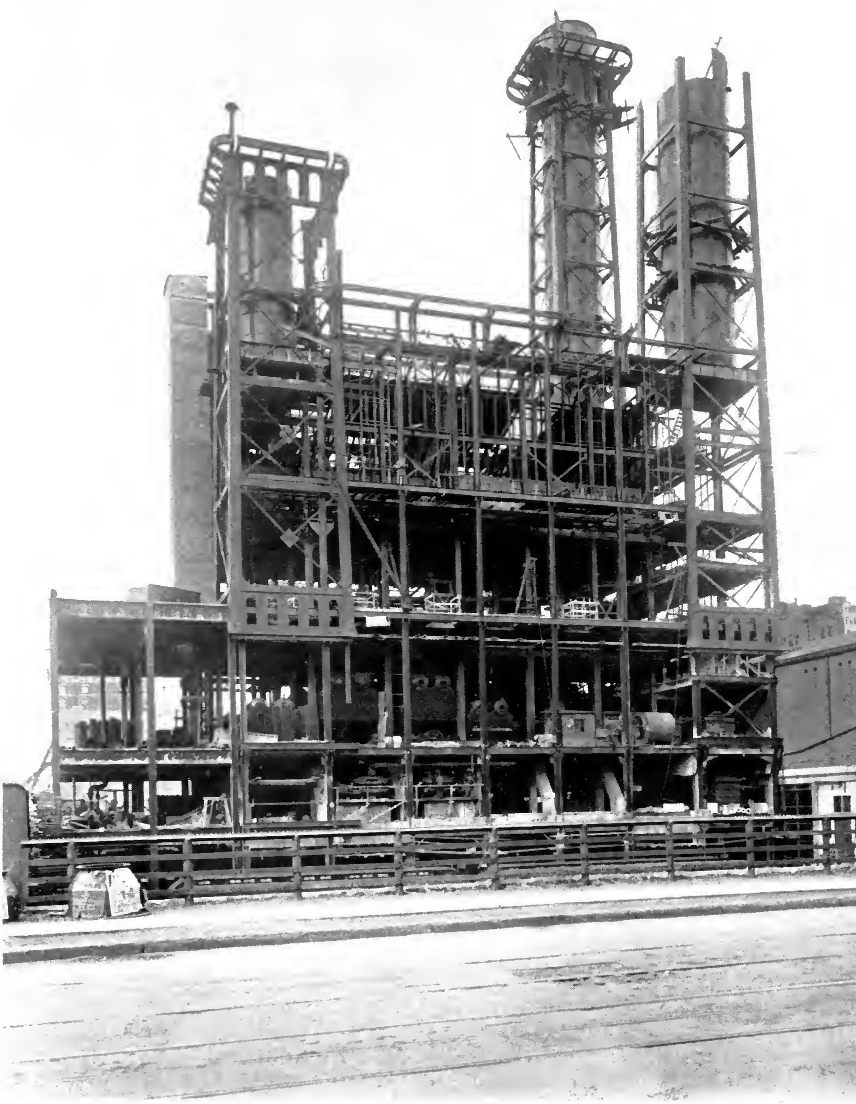
The heat values of the above are as follows:

	7840 B. T. U.	5880 B. T. U.
Equivalent to	8.1 lbs of water	6.1 lbs of water

evaporated per lb. of fuel from and at 212°F theoretically.

From the above it will be seen that there is a loss of heating power per lb. of ordinary fire wood of 25%, due to the presence of the hygrometric water, and there is a still further loss of 5% due to the fact that this water must be evaporated.

Suppose the wood with its contained water to be fed onto the fire at the ordinary temperature of 62°F. Each lb. of water therefore will require about 1116.6 B. T. U. to heat it up to 212°F. and evaporate it at this temperature, and as each lb. of wood by above analysis contains ¼ lb. of water, this will require 279 heat units to evaporate it, which is 4.7% of the total heat generated, so that ordinary fire wood has only about 71% of the heat value of perfectly dry wood. The A. S. M. E. have established a value of wood in its equivalent in coal for the purpose of boiler testing as above stated, viz: 1 lb. of wood = 0.40 lbs. of coal,



6000 H. P. OF HEINE BOILERS AND SUPERHEATERS, IN PROCESS OF ERECTION IN POWER HOUSE OF THE GRAND CENTRAL STATION N. Y. C. AND H. R. R. R. CO., NEW YORK, N. Y.

but in case greater accuracy is desired, 1 lb. of wood may be considered as having a heat value equivalent to the evaporation of six lbs. of water from and at 212°F., which is equivalent to 5794 B. T. U's. per lb.

Table No. 25

COMPOSITION OF WOOD.

(GOTTLIEB AND CHEVANDIER.)

Woods	Carbon	Hydrogen	Oxygen	Nitrogen	Ash
Beech	49.36%	6.01%	42.69%	0.91%	1.06%
Oak	49.64	5.92	41.16	1.29	1.97
Birch	50.20	6.20	41.62	1.15	0.81
Poplar	49.37	6.21	41.60	0.96	1.86
Willow	49.96	5.96	39.56	0.96	3.37
Ash	49.18	6.27	43.91	0.07	0.57
Elm	48.99	6.20	44.25	0.06	0.50
Fir	50.36	5.92	43.39	0.05	0.28
Pine	50.31	6.20	43.08	0.04	0.37

WEIGHT OF WOOD PER CORD.

Kind of Wood.	Weight.	Kind of Wood.	Weight
Hickory, shell bark	4469	Beech	3126
" redheart	3705	Hard Maple	2878
White oak	3821	Southern pine	3375
Red oak	3254	Virginia pine	2680
Spruce	2325	Yellow pine	1904
New Jersey pine	2137	White pine	1868

TAN BARK.

Tan bark, usually oak bark after having been used in the process of tanning, is frequently burned as fuel. The spent bark consists of the fibrous portions and according to M. Peclet, five parts of oak bark produces four parts of dry tan, the heat value of which is about 6100 B. T. U., and this so-called dry tan contains about 15% of ash. Tan bark in its ordinary state of dryness contains about 30% of water, and has a heat value of 4284 B. T. U. The theoretical evaporation from and at 212°F. of 1 lb. of spent bark equivalent to the above heating power is about 4.12 lbs. water.

To burn wet tan bark successfully, it should be done in a furnace of sufficient volume to accommodate a large quantity of wet bark, exposed to the heated gases coming from the burning bark, which has been previously dried. As the wet bark becomes dried, it must be fed down and burned, where its hot gases in turn assist in drying the newly fed

fuel. The rate of combustion is limited by the rapidity of the drying process. If it exceeds this the dry portion burns up completely, leaving the wet fuel which refuses to burn.

STRAW.

Straw consists of the stems or stalks of grain, and its principal use is for plaiting, thatching, paper making, etc., but in certain localities it is used as a fuel. The composition of straw in its ordinary air dried condition is given by Mr. John Head as follows:

Table No. 26

	Wheat Straw	Barley Straw	Mean
	%	%	%
Carbon	35.86	36.27	36.00
Hydrogen	5.01	5.07	5.00
Oxygen	37.68	38.26	38.C0
Nitrogen	.45	.40	.425
Ash	5.00	4.50	4.75
Water	16.00	15.50	15.75
	100.00	100.00	100.00

Its heat value as shown by the mean composition above is 5411 B. T. U. out of which 153 B. T. U. must be used in evaporating the natural water, leaving 5258 B. T. U. available, which is equivalent to the evaporation of 5.4 lbs. of water per lb. of straw from and at 212°F.

BAGASSE.

Bagasse is the fibrous portion of sugar cane left after the juice has been extracted from it in the mill and consists of water, woody fibre, sucrose, glucose and other solids in varying proportions depending upon the quality of the cane and its treatment in the mill. According to Prof. E. W. Kerr's experiments the moisture content varies from 50 to 56 per cent in the Louisiana cane and from 44 to 52 per cent in the tropics and the average heat value per pound of dry bagasse is 8360 B. T. U.

Assume a bagasse containing 50% moisture, a boiler room temperature of 70°F. and a stack temperature of 500°F. To raise the temperature of the contained moisture in one pound of wet bagasse from 70°F. to 212°F., evaporate it and then raise the temperature of the vapor thus formed to 500°F. will require:—

$$.5 [(212 - 70) + 970.4 + .5(500 - 212)] = 628 \text{ B. T. U.}$$

where the first term in the bracket represents the heat necessary to raise the temperature of the water from 70° to 212°F., the second term the latent heat of vaporization at atmospheric pressure, and the last term the degrees of superheat multiplied by the specific heat of superheated steam at atmospheric pressure.

If the dry bagasse contains 8360 B. T. U's. per pound the wet bagasse will contain $.50 \times 8360 = 4180$ B. T. U. It takes 628 B. T. U. to evaporate the contained moisture, therefore the net heat available will be $4180 - 628 = 3554$ B. T. U. per pound of bagasse as fired.

Table No. 27 gives the net heat value of bagasse with varying percentages of contained moisture.

Table No. 27

Moisture percent	Net calorific value per pound of bagasse, B. T. U.
60	2599
56	2977
54	3170
52	3360
50	3554
48	3746
46	3938
44	4131
42	4323
40	4515

The proportion of this net heat which will be given to the water inside the boiler depends on the efficiency of the boiler and furnace. If the efficiency of the boiler plant is 65 per cent we would have an equivalent evaporation of $\frac{.65 \times 3554}{970.4} = 2.31$ pounds of water from and at 212°F.

Table No. 28 compiled by Prof. Kerr gives a comparison between bagasse of different extractions, coal and fuel oil.

The following are some of the conclusions reached in Louisiana Bulletin No. 117:

"Less excess of air is required with bagasse than with coal, usually 50% or less is sufficient

The rate of combustion should be at least 100 pounds per square foot of grate surface per hour, and best results were obtained with rates even higher than this.

HUDSON CO. COURT HOUSE AND JAIL, JERSEY CITY, N. J., CONTAINS 1000 H. P. OF HEINE BOILERS.

Table No. 28

		Total Solids				Heat absorbed by the dry gases of combustion.			Available heat for evaporation allowing 5% for radiation B. T. U.			Lbs. of Bagasse required to equal 1 lb. of Coal of 14000 B. T. U. calorific value			Lbs. of Bagasse required to equal one gal. of Fuel Oil of .915 sp. gr. and 19000 B. T. U. calorific value. 1 gal. of above equal 7.62 lbs.			Lbs. of Water 1 lb. of Bagasse can evaporate from and at 212° F.			Theoretical furnace temp.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Percent of Extraction	Percent of Moisture in Bagasse	Percent of Fiber in Bagasse	Percent of Sugars and Non-Sugars in Bagasse	The total heat value of one lb. of Bagasse B.T.U.	Heat absorbed by the free moisture and moisture at formation	No excess air	50 per cent excess air	100 per cent excess air	No excess air	50 per cent excess air	100 per cent excess air	No excess air	50 per cent excess air	100 per cent excess air	No excess air	50 per cent excess air	100 per cent excess air	No excess air	50 per cent excess air	100 per cent excess air	No excess air	50 per cent excess air	100 per cent excess air
THE VALUE OF ONE POUND OF UNMACERATED MILLED BAGASSE AT DIFFERENT EXTRACTIONS UPON CANES OF 10% FIBRE AND JUICE WITH 15% TOTAL SOLIDS. REPRESENTING LOUISIANA CONDITIONS. ASSUMING 80°F. FIRE ROOM AND 500°F. STACK TEMPERATURE.																							
70	56.7	33.3	10.0	3626	1023	276	403	530	2209	2090	1970	6.34	6.70	7.11	65.5	69.2	73.5	2.29	2.16	2.04	2722	2150	1800
75	51.0	40.0	9.0	4100	986	308	453	594	2666	2528	2394	5.25	5.54	5.85	54.4	57.3	60.5	2.76	2.62	2.48	3038	2360	1943
80	42.8	50.0	7.5	4816	936	359	528	694	3345	3184	3027	4.18	4.40	4.62	43.2	45.4	47.8	3.46	3.30	3.13	3443	2602	2140
THE VALUE OF ONE POUND OF UNMACERATED MILLED BAGASSE AT DIFFERENT EXTRACTION UPON CANE OF 12% FIBRE AND JUICE WITH 18% TOTAL SOLIDS. REPRESENTING TROPICAL CONDITIONS ASSUMING 80°F. FIRE ROOM AND 500°F. STACK TEMPERATURE.																							
70	49.2	40.0	10.8	4254	986	318	466	610	2792	2662	2525	5.02	5.26	5.54	51.8	54.3	57.3	2.89	2.76	2.62	3118	2430	1987
75	42.6	48.0	9.4	4807	936	360	530	694	3335	2174	3018	4.20	4.41	4.64	43.4	45.6	48.0	3.45	3.28	3.12	3436	2600	2135
80	32.8	60.0	7.2	5628	886	435	630	833	4092	3906	3713	3.42	3.59	3.78	35.4	37.0	39.0	4.24	4.05	3.48	3702	2782	2253

Not less than 1.5 boiler horsepower should be provided per ton of cane per 24 hours.

A good working furnace depends more upon the proportion of heating surface to the grate surface, rate of combustion and other matters of design and operation than upon the type or form.

On account of the large amount of moisture in bagasse which is converted into steam in the furnace, a volume of gas and steam much larger than for coal must be provided for in the combustion chamber and the passages to the stack."

BROWN PALACE HOTEL, DENVER, COL., CONTAINS 1000 H. P. OF HEINE BOILERS.

FUEL OILS.

The great production of petroleum in the last few years has made it of prime importance as a boiler fuel. The following taken from the U. S. G. S. Reports of 1908-1909 shows how rapid this increase has been:

Table No. 29

Years	Production in bbls. of 42 gals.	Total Value
1859-68	23,488,534	89,398,850
1869-78	88,462,318	199,197,919
1879-88	257,698,609	211,200,848
1889-98	513,262,365	384,548,840
1899-1908	1,103,269,116	900,237,486
1909	182,134,274	128,248,873

Table No. 30

PRODUCTION OF PETROLEUM IN THE SEVERAL STATES IN 1908.

State	Rank.	Quantity. Bbls.	Percentage.
Oklahoma	1	45,798,795	25.50
California	2	44,854,737	24.98
Illinois	3	33,685,106	18.76
Texas	4	11,206,464	6.24
Ohio	5	10,858,797	6.05
West Virginia	6	9,523,176	5.30
Pennsylvania	7	9,424,325	5.25
Louisiana	8	6,835,130	3.80
Indiana	9	3,283,629	1.83
Kansas	10	1,801,781	1.00
New York	11	1,160,128	.65
Kentucky, Tennessee	12	727,707	.41
Colorado	13	379,653	.21
Utah, Wyoming	14	17,775	.02
Michigan, Missouri	15	15,246	
		179,572,479	100.00

There were 13 railroad companies that used fuel oil on their lines in 1908. The aggregate fuel consumption was 16,889,070 barrels. The estimated mileage covered by oil-burning engines on these roads was 64,347,357 miles in 1908, an average of 3.81 miles per barrel of oil consumed.

Mr. B. R. T. Collins, in Power for May 16, 1911, gives the following advantages and disadvantages of Fuel Oil.

ADVANTAGES.

1. Calorific value per pound 30% higher than that of high-grade coal, less weight of oil being required for the same heating effect.

2. Space required for storage of oil is less than that for an equal weight of coal.

3. Oil does not deteriorate by storage.

4. Lower temperature in the boiler room.

5. Area of stack 60% of that required for coal for equal boiler capacity, thus enabling a plant having insufficient draft with coal to have an excess amount with oil, a change from coal to oil making the installation of additional stack capacity unnecessary.

6. Less heat loss up the stack, owing to cleaner condition of the tubes and to the smaller amount of air which has to pass through furnace for a given calorific capacity of fuel.

7. Higher efficiency due to more perfect combustion with less excess air, more equal distribution of heat in combustion chamber, as doors do not have to be opened and very little soot is deposited on the tubes.

8. Increase in capacity over coal.

9. Heat is easier on metal surfaces, being better diffused over the entire heating surface of the boiler.

10. Ease with which fire can be regulated from a low to a most intense heat in a short time or entirely extinguished instantly in case of emergency, such as water dropping out of sight in gage glass, and quickly relighted when the emergency is over. In less than half an hour a boiler can be brought up to 150 pounds steam pressure from cold water, if necessary.

11. Smoke can be entirely eliminated.

12. No cleaning of fires.

13. Much lower cost for handling oil than handling coal.

14. Absence of coal dust and ashes.

15. No firing tools used, consequently, no damage to furnace linings from this source. No clinkers to be removed from grate bars or furnace side walls.

16. Saving in labor of all kinds.

DISADVANTAGES.

1. Low flash point. Fuel oil should have a flash point not lower than 140°F., and with oil of this quality, handled by men of ordinary intelligence and common sense, there is practically no more danger than with coal.

2. The ordinary underwriters' or city requirements specify that storage tanks for fuel oil be located underground and at least 30 feet from the nearest building. This can generally be complied with in the case of the power plant of the average manufacturing concern, but in the case of a plant in the congested districts of a city it is likely to be prohibitive.

3. With boilers using feed water of considerable scale-making qualities, the cost of repairs is likely to be increased by changing to oil, owing to the intense temperature developed in the furnace.

The U. S. Naval Liquid Fuel Board appointed for the purpose of thoroughly investigating the problem of using oil as a boiler fuel, made an exhaustive report to the Navy Department. Their conclusions are given in full and while relating particularly to marine practice, there is much that is applicable to land practice.

CONCLUSIONS OF THE U. S. NAVAL LIQUID FUEL BOARD.

a. That oil can be burned in a very uniform manner.

b. That the evaporative efficiency of nearly every kind of oil per pound of combustible is probably the same. While the crude oil may be rich in hydrocarbons, it also contains sulphur, so that, after refining, the distilled oil has probably the same calorific value as the crude product.

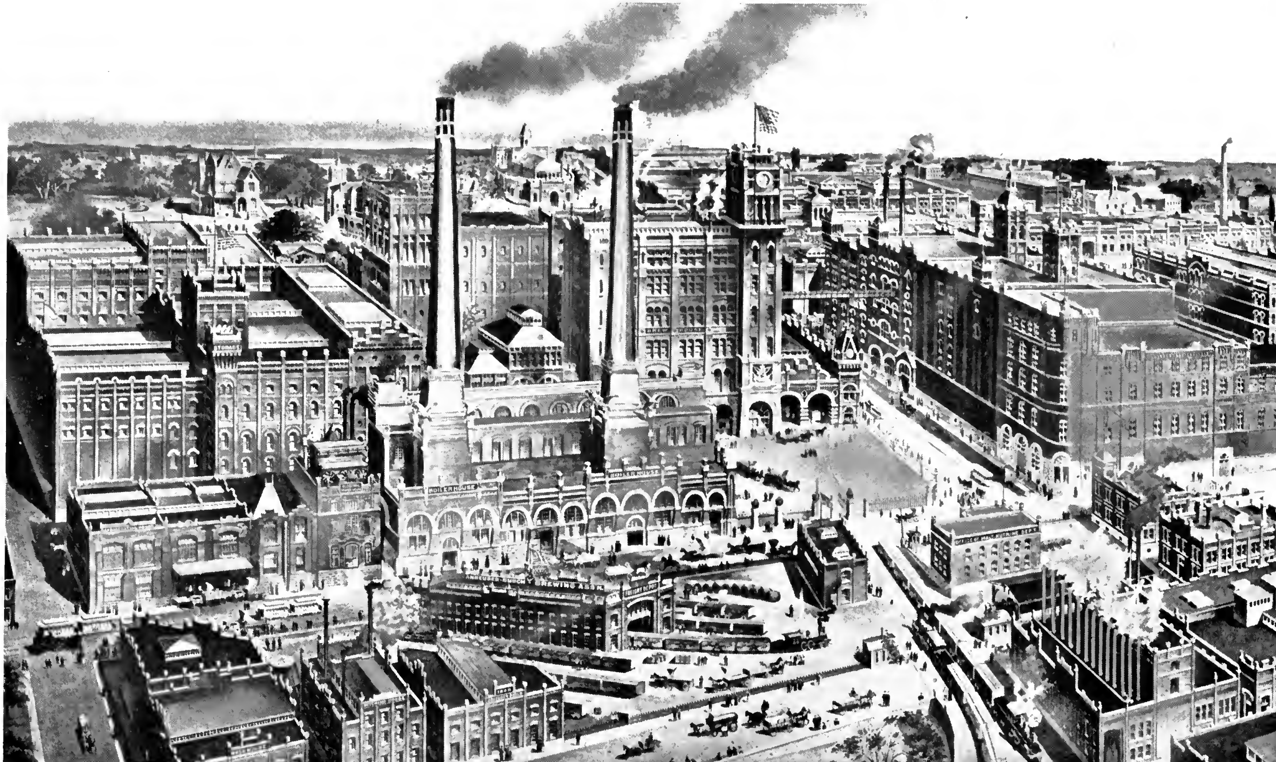
c. That a marine steam generator can be forced to even as high a degree with oil as with coal.

d. That up to the present time no ill effects have been shown upon the boiler.

e. That the firemen are disposed to favor oil, and therefore no impediment will be met in this respect.

f. That the air requisite for combustion should be heated if possible before entering the furnace. Such action undoubtedly assists the gasification of the oil product.

g. That the oil should be heated, so that it could be atomized more readily.



ANHEUSER BUSCH BREWERY, ST. LOUIS, MO.
CONTAINS 14,000 H. P. OF HEINE BOILERS.

Table No. 31

ANALYSES OF TYPICAL AMERICAN FUEL OILS.

Location.	Authority.	Specific Gravity 60°-70°F.	Physical Properties.				Chemical Properties.				
			Flash Point Deg. F.	Burning Point Deg. F.	Specific Viscosity 60°F.	Specific Viscosity 185°F.	C	H	O+N	S	B. T. U. per lb.
California-Crude	Ed. O'Neil	0.9533	...	.....	299.6	4.7	85.75	11.3	.....	0.668	18,797
“	“	0.9572	...	.....	373.0	...	86.3	10.7	.....	0.8	18,646
“	“	0.7825	62	64.5	1.17	...	.....	.....	.....	.....	......
“	“	0.9670	196	221	......	...	.....	.....	.....	.....	......
Kansas-Crude	B. F. McFarland	0.866	52	77	......	...	85.4	13.07	.....	.....	......
Lousiana-Crude	C. E. Coates	......	...	.....	......	...	.....	.....	.....	0.34	19,814
Ohio-Distillate	Deville	0.8870	...	.....	......	...	84.2	13.1	2.7	.....	18,718
“	N. W. Lord	0.838	177	212	......	...	.....	.....	.....	.....	19,880
Pennsylvania-Crude	Deville	0.8260	...	.....	......	...	82	14.8	3.2	.....	17,930
Penna-Distillate	“	0.8860	...	.....	......	...	84.9	13.7	1.4	.....	19,210
W. Virginia-Crude	“	0.841	...	.....	......	...	84.3	14.1	1.6	.....	18,400
Wyoming-Crude	Colburn	......	...	.....	......	...	.....	.....	.....	.....	19,590
Texas-Crude	Denton	0.92	142	181	......	...	84.6	10.9	2.87	1.63	19,060
Texas-Distillate	U. S. Naval Report	0.926	216	240	......	...	83.26	12.41	3.83	0.50	19,481

h. That when using steam higher pressures are undoubtedly more advantageous than lower pressures for atomizing the oil.

i. That under heavy forced draft conditions, and particularly when steam is used, the Board has not yet found it possible to prevent smoke from issuing from the stack, although all connected with the tests made special efforts to secure complete combustion. Particularly for naval purposes, it is desirable that the smoke nuisance be eradicated in order that the presence of a war ship might not be detected from this cause. As there has been a tendency of late to force the boilers of industrial plants, the inability to prevent the smoke nuisance under forced-draft conditions may have an important influence upon the increased use of liquid fuel.

j. That the consumption of liquid fuel cannot probably be forced to as great an extent with steam as the atomizing agent as when compressed air is used for this purpose. This is probably due to the fact that the air used for atomizing purposes, after entering the furnace, supplies oxygen for the combustible, while in the case of steam the rarified vapor simply displaces air that is needed to complete combustion.

k. That the efficiency of oil-fuel plants will be greatly dependent upon the general character of the installation of auxiliaries and fittings, and therefore the work should be intrusted only to those who have given careful study to the matter and who have had extended experience in burning the crude product. The form of the furnace will play a very small part in increasing the use of crude petroleum. The method and character of the installation will count for much, but where burners are simple in design and are constructed in accordance with scientific principles there will be very little difference in their efficiency. Consumers should principally see that they do not purchase appliances that have been untried and have been designed by persons who have had but limited experience in operating oil devices.

FUEL GAS.

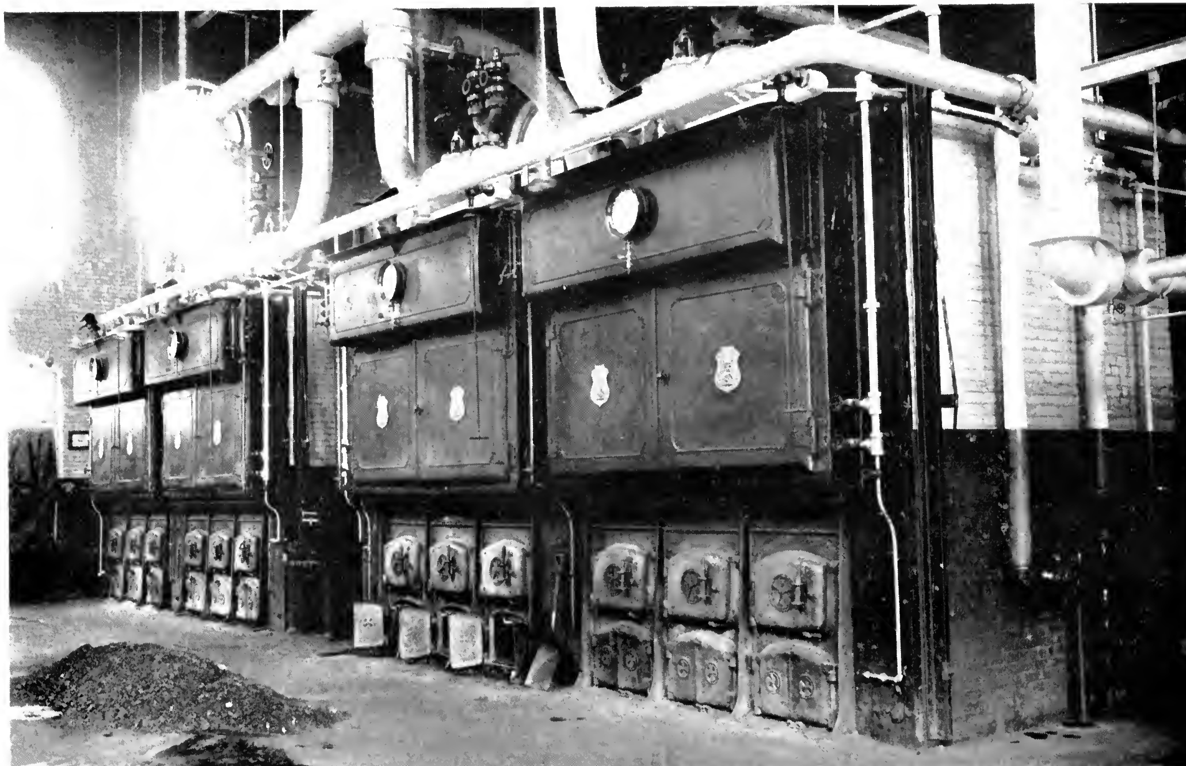
Gaseous Fuel has so many apparent advantages over any other that it may properly be regarded as the ideal fuel. Manufacturers who have once realized its advantages, would gladly welcome some kind of gaseous fuel, provided this can be made cheap enough to compete with the local coal. To answer this demand a number of processes have been invented. The U. S. Geological Survey in its report on the Mineral Resources of the United States, reports the production of natural gas in 22 states. In some of these states such quantities are produced that immense industrial operations are based on its use.

Table No. 32 gives the relative compositions of natural and artificial gases by volume and by weight.

Table No. 32

COMPOSITION OF NATURAL AND ARTIFICIAL GASES.

Elements	Chemical Symbol	Nat. Gas		Coal Gas		Water Gas		Producer Gas	
		Vol.	Wt.	Vol.	Wt.	Vol.	Wt.	Vol.	Wt.
Hydrogen	(H)	2.18	0.268	46.00	8.21	45.00	5.431	6.00	0.458
Marsh Gas	(CH_4)	92.60	90.383	40.00	57.20	2.00	1.931	3.00	1.831
Carbon Monoxide	(CO)	0.50	0.857	6.00	15.02	45.00	76.041	23.50	25.095
Olefiant Gas	(C_2H_4)	0.31	0.531	4.00	10.01	0.00	0.000	0.00	0.000
Carbon Dioxide	(CO_2)	0.26	0.700	0.50	1.97	4.00	10.622	1.50	2.517
Nitrogen	(N)	3.61	6.178	1.50	3.75	2.00	3.380	65.00	69.413
Oxygen	(O)	0.34	0.666	0.50	1.43	0.50	0.965	0.00	0.000
Water Vapor	(H_2O)	0.00	0.000	1.50	2.41	1.50	1.630	1.00	0.686
Sulphydric Acid	(H_2S)	0.20	0.417	.....	.....	.....	.....	.....	.....
		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00



FOUR 302 H. P. HEINE BOILERS, MONOMAC SPINNING CO., LAWRENCE, MASS.

Table No. 33 shows the relative heat values of the four gases in the previous table, and a comparison of each with soft coal. The coal is assumed to cost $2.00 per ton and to have a heat value of 13500 B. T. U. The efficiency of the two fuels is assumed to be the same when burned under a boiler. The last column shows what price should be paid for the gas in order to make it economical to use that fuel. No account has been taken of the saving resulting from the less attention needed, the probably higher efficiency, the fact that that there are no ashes to remove, and the greater ease of handling when gas is used. These factors would make it possible to pay a higher rate for gas depending on the size of plant and the relative importance of the various items mentioned. As an approximation it may be said that it does not pay to use natural gas if it costs more than 10 cents per 1000 cu. ft., and the others in proportion.

Table No. 33

COMPARISON OF GAS AND COAL.

Variety	Heat Units per 1000 cu. ft.	Equivalent pounds of coal.	Corresponding price per 1000 cu. ft.
Natural Gas.............	1,100,000	81.5	8.15 Cents
Coal Gas................	755,000	55.9	5.59 "
Water Gas..............	350,000	25.9	2.59 "
Producer Gas...........	155,000	11.48	1.148 "

Table No. 34

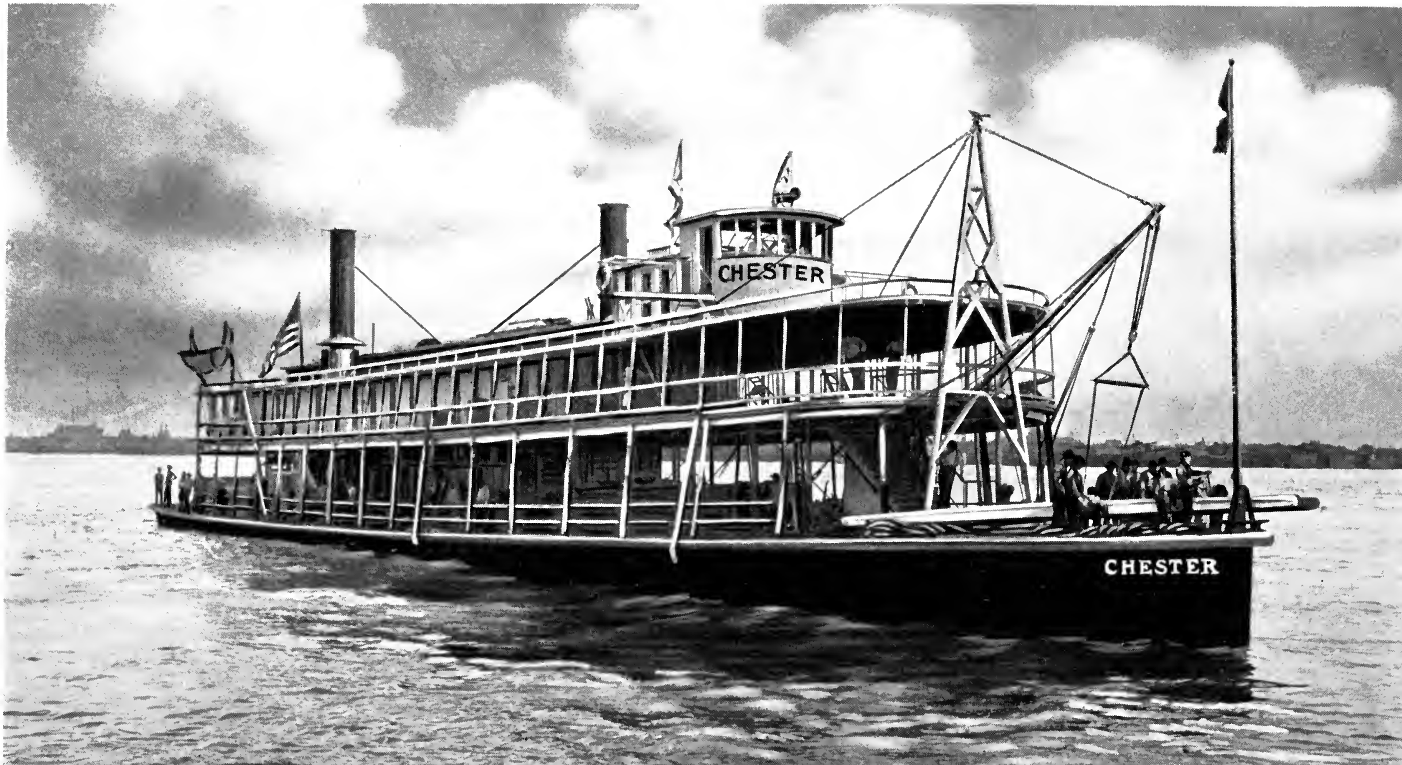
CU. FT. OF GAS REQUIRED PER HP. PER HR.

Variety.	100 per cent efficiency.	80 per cent efficiency.	70 per cent efficiency.	60 per cent efficiency.
Natural Gas.......	30.4	38.0	43.5	50.7
Coal Gas..........	44.4	55.5	63.6	74.0
Water Gas........	95.6	119.5	136.5	159.2
Producer Gas......	216.0	270.0	308.6	360.0

Table No. 35

WATER EVAPORATION ON BASIS OF 75 PER CENT BOILER EFFICIENCY.

	Natural Gas.	Coal Gas.	Water Gas.	Producer Gas.
Pounds water from and at 212°F. per 1000 cu. ft. Gas.	851	584	270.5	120



MISSISSIPPI RIVER STEAMBOAT "CHESTER," KANSAS CITY-MISSOURI RIVER NAVIGATION CO., FITTED WITH TWO 260 H. P. HEINE BOILERS, FOR 250 LBS. PRESSURE.

Experiments have shown that the type of burner seems to have very little effect on the efficiency of the combustion. Opinions are about equally divided, also, on the kind of flame which is best. A blue flame indicates perfect combustion and a white flame indicates imperfect combustion; but perfect combustion may exist beyond the white flame, provided enough air is supplied to unite with the unconsumed particles of carbon. If the latter state exists then the two flames should give the same efficiency. In practice it is usua to have a flame which is part white and part blue.

Table No. 36

QUANTITY AND VALUE OF NATURAL GAS PRODUCED AND CONSUMED IN THE UNITED STATES IN 1906, 1907 AND 1908. U. S. G. S. 1908.

Domestic Quantity M Cubic Feet.	Industrial Quantity M Cubic Feet.	Total. Quantity M Cubic Feet.	Cents per M Cubic Feet.	Value Dollars
1906—110,405,808	278,436,754	388,842,562	12.1	46,873,932
1907—131,377,587	275,244,532	406,622,119	13.33	54,222,399
1908—140,583,732	261,556,998	402,140,730	13.59	54,640,374

LAYING OUT AND INITIAL PROCESSES, HEINE SAFETY BOILER CO. SHOP, ST. LOUIS, MO.

RIDGEWOOD PUMPING STATION, BROOKLYN, N. Y. CONTAINS 2400 H. P. OF HEINE BOILERS.

WATER.

PURE water, whether in the solid, liquid or gaseous state is a chemical combination of the two elements hydrogen and oxygen. These two gases when combining chemically, always do so in the proportion of two parts by volume of hydrogen with one part of oxygen. If the two gases are mixed while cold in the above proportions the mixture is merely a mechanical one until through the influence of heat, electricity or some other special agent, the two combine chemically. If a lighted taper be introduced into a vessel containing a cold mixture of the two gases in proper proportions they will combine, forming water, which will be found deposited on the inside of the containing vessel. If the union of the two gases be brought about in a vessel so arranged that the resulting water is maintained at a high temperature, it will retain its gaseous condition and the two volumes of hydrogen and the one volume of oxygen will be found to have become compacted into two volumes of steam as the result.

Conversely, two volumes of steam may be dissociated by the application of heat into its constituent elements, namely two volumes of hydrogen and one volume of oxygen. Consequently the presence of moisture in fuels may assume importance in the ordinary process of combustion.

WEIGHT AND BULK OF WATER.

Water has been universally adopted as the standard by which the relative weights of other liquids and solids are determined, this relation being expressed by the term "Specific Gravity". The specific gravity of any body therefore indicates its weight as compared with the weight of an equal volume of pure water. Unfortunately there is a considerable difference in the weights of water at different temperatures as given by various authorities and experimenters, and until a further determination of these quantities shall have been made by some person of experience assisted by the use of modern and refined instruments and processes, the question must remain in its present state of uncertainty. However the differences in the results found by different investigators are all in the decimal parts and are mostly in the second and third place, so that unless for very refined calculations, the information given in Table No. 39 (page 80) following will be found sufficiently accurate. This has been compiled from standard publications and is correct as far as is known. It will be noted that both the volume and weight per cubic foot change with the temperature and in fairly regular and increasing differences.

Table No. 37

PRESSURES IN POUNDS PER SQUARE INCH AND HEADS OF WATER CORRESPONDING.

(KENT)

Head in Feet	0	1	2	3	4	5	6	7	8	9
0		0.433	0.866	1.299	1.732	2.165	2.598	3.031	3.464	3.897
10	4.330	4.763	5.196	5.629	6.062	6.495	6.928	7.361	7.794	8.227
20	8.660	9.093	9.526	9.959	10.392	10.825	11.258	11.691	12.124	12.557
30	12.990	13.423	13.856	14.289	14.722	15.155	15.588	16.021	16.454	16.887
40	17.320	17.753	18.186	18.619	19.052	19.485	19.918	20.351	20.784	21.217
50	21.650	22.083	22.516	22.949	23.382	23.815	24.248	24.681	25.114	25.547
60	25.980	26.413	26.846	27.279	27.712	28.145	28.578	29.011	29.444	29.877
70	30.310	30.743	31.176	31.609	32.042	32.475	32.908	33.341	33.774	34.207
80	34.640	35.073	35.506	35.939	36.372	36.805	37.238	37.671	38.104	38.537
90	38.970	39.403	39.836	40.269	40.702	41.135	41.568	42.001	42.436	42.867
100	43.300									

$\frac{\text{Wt. per Cubic Foot}}{144}$ = Pres. per sq. in. for 1 ft. head. For this table $\frac{62.352}{144}$ = 0.433 lbs. for 1 ft. head.

Table No. 38

HEAD IN FEET OF WATER AND PRESSURES IN POUNDS PER SQUARE INCH CORRESPONDING.

(KENT)

Pressure	0	1	2	3	4	5	6	7	8	9
0		2.309	4.619	6.928	9.238	11.547	13.857	16.166	18.476	20.785
10	23.095	25.404	27.714	30.023	32.333	34.642	36.952	39.261	41.570	43.880
20	46.189	48.499	50.808	53.118	55.427	57.737	60.046	62.356	64.665	66.975
30	69.284	71.594	73.903	76.213	78.522	80.831	83.141	85.450	87.760	90.069
40	92.379	94.688	96.998	99.307	101.617	103.926	106.236	108.545	110.855	113.164
50	115.474	117.783	120.093	122.402	124.712	127.021	129.330	131.640	133.949	136.259
60	138.568	140.878	143.187	145.597	147.806	150.116	152.425	154.734	157.044	159.353
70	161.663	163.972	166.282	168.591	170.901	173.210	175.520	177.829	180.139	182.448
80	184.768	187.067	189.377	191.686	193.995	196.305	198.614	200.924	203.233	205.543
90	207.852	210.162	212.471	214.781	217.090	219.400	221.709	224.019	226.328	228.638
100	230.947									

$\frac{1}{\text{Lbs. pressure per sq. in.}} = \text{Ft. Head.}$ For this table $\frac{1}{0.433} = 2.30947$ Ft. Head.

Table No. 39

WEIGHT OF ONE CUBIC FOOT OF WATER AT VARIOUS TEMPERATURES.

Temp., Degs. F.	Weight per Cubic Foot.	Temp., Degs. F.	Weight per Cubic Foot.	Temp., Deg. F.	Weight per Cubic Foot.	Temp., Deg. F.	Weight per Cu. Ft.
32	62.416	85	62.182	145	61.291	205	59.930
35	62.422	90	62.133	150	61.201	210	59.880
39.1	62.425	95	62.074	155	61.096	212	59 833
40	62.425	100	62.022	160	60.991	220	59.630
45	62.420	105	61.960	165	60.843	230	59 370
50	62.409	110	61.868	170	60.783	250	58.830
55	62.392	115	61.807	175	60.665	270	58.260
60	62.372	120	61.715	180	60.548	290	57.650
62	62.355	125	61.654	185	60.430	300	57.330
65	62.344	130	61.563	190	60.314	330	56.300
70	62.313	135	61.472	195	60.198	360	55.180
75	62.275	140	61.381	200	60.120	390	53.940
80	62.232					420	52.600

EXPANSION AND CONTRACTION OF WATER.

Water is only very slightly compressible. Its compressibility decreases with increase of temperature. For each foot of pressure pure water will be diminished in volume from .0000013 to .0000015. Although water is practically incompressible even under the highest temperatures it readily expands by the application of heat with the exception that between the temperatures of melting ice at 32° and that of its point of greatest density 39.1°, there is a gradual contraction in volume as heat is applied, as will readily be noted in Table No. 39.

SPECIFIC HEAT OF WATER.

Different substances vary much in their capacity for absorbing heat under equal changes in temperature, which relation is expressed by the term "Specific Heat". This means the quantity of heat necessary to raise the temperature of a substance one degree, as compared to the quantity of heat which is required to raise an equal weight of water one degree, from 62°F. to 63°F. As the specific heat of water is greater than that of any other known substance, the specific heat of all other substances must of necessity be expressed in decimals. The specific heat of water is not constant, as it varies with the temperature, but as this variation is extremely slight it need not be considered except in very refined calculations.

IMPURITIES IN WATER.

"A steam-boiler is a steam-generator, not a kettle for chemical reaction.

"Get, if possible, a supply of clean, soft, natural water.

"The only compound to put into a boiler is pure water.

"Oxygen, the most useful element, is, when free in boilers, a most destructive corrosive element.

Water as found in nature, is never pure being always more or less contaminated by impurities. In boiler practice these impurities have very serious effects and not only militate against economy of operation but may even jeopardize the life of the boiler itself.

The purification of water is a chemical rather than an engineering problem and it is not the purpose to here specify any particular treatment, but simply to state conditions as they frequently exist, and in a general way outline the remedies.

The various impurities which may be found in any water by a careful chemical analysis, may be made harmless by the use of such chemicals as will render them insoluble before the water is used.

The impurities most commonly found in waters are the following:

Earthy matters, bi-carbonates of lime and magnesia, iron, sulphates of lime, chlorides and sulphates of magnesium, carbonate of soda in large amounts, acids, dissolved carbonic acid and oxygen, grease and organic matter. Impurities are commonly reported as the number of parts per one thousand or one hundred thousand. A larger amount than one hundred parts total solids per 100,000 parts of water should in most cases condemn the water for use in steam boilers.

The effects of the impurities if not neutralized are as follows:

Incrustation, caused by readily soluble salts, bi-carbonate of lime and magnesia, iron and sulphate of lime.

Corrosion, caused by chloride and sulphate of magnesium, acids and dissolved carbonic acid and oxygen.

Priming, caused by the presence of large amounts of carbonate of soda, calcium and magnesium, grease, and organic matter, such as sewage.

The chemicals generally used to treat the impurities are caustic soda, lime or magnesia, carbonate of soda, barium chloride, milk of lime, alum, or ferric chloride, filtration and heating which may be used alone or to supplement the chemicals.

Such remedial agents may be used in any of the following manners:

First by treating the water to be used, with such chemicals and coagulents as are indicated by a careful chemical analysis, in large quantities and in special large tanks, so constructed that the re-agents may be

AYER MILLS OF THE AMERICAN WOOLEN CO., LAWRENCE, MASS., CONTAINS 4800 H. P. OF HEINE BOILERS.

introduced, each in the required amount, continuously and automatically; or by having means provided for heating the water and with ample space where sedimentation may take place. Ample storage for the purified water must be provided so that the intermittent purifying processes may not interfere with the regular supply of pure water to the boilers. It is also frequently desirable to filter the purified water. The impurities thus deposited as solids may be removed from time to time.

Secondly by the regular and constant addition to the feed water, as it is supplied to the boiler, of the necessary remedial agents as indicated by the analysis, in amounts proportional to the untreated water being used. This is frequently done by attaching a proper mechanism to the suction pipe of the boiler feed pump. This treatment is designed to change the impurities into combinations which are always soluble and which are disposed of by blowing off the boiler as often as required.

Thirdly by pumping into the boiler at stated intervals, a quantity of some combination of remedial agents calculated to neutralize the various objectionable matters which may be present in the water, in such amounts as may be prescribed to cover a selected interval of time; when another dose of the compound is pumped in. The effect of this method is the same as the one preceding.

In a general way it may be stated that the method as outlined in the first system is the best wherever the necessary room or space is available, as the entire process is completed outside of the boilers and entirely independent of them. No special machinery, excepting possibly a pump, is needed, and this only in cases where gravity pressure is not available.

Where water is obtained from a driven or bored well, and must in any event be pumped to the surface, the same pumping machinery may readily be arranged to also elevate the water to a height sufficient to enable the subsequent handling through the tanks to be done by gravity.

The only objection which can be raised against this method is the room required for the necessary treatment and storage tanks and the cost of the apparatus itself. The treatment is not at all expensive and wherever large quantities of water are used or where the impurities to be neutralized are such as to require time; or where a rather complicated treatment is demanded, this method is very much the best.

The second method is desirable only where the quantity of impurities is comparatively small, and of such a character as do not call for any complicated treatment. It has the objection that the chemical reactions must take place usually in a very short time in a much restricted space, and that the blowing off must be regularly attended to since the boiler water is constantly becoming more nearly saturated with the foreign compounds, thus inducing foaming and priming.

The third mehod is the least desirable of all. As usually practiced it consists in placing a quantity of some compound of indefinite composition in a boiler when the periodical washing out is completed and the boiler is being filled preparatory to being put back into service. Unless specially compounded by a competent chemist, after a careful analysis has been made of the water, these mixtures frequently do more harm than good. As a steam boiler is a particularly undesirable place in which to make chemical experiments, their use should be discouraged except under special conditions.

OIL IN BOILERS.

Oil or grease must be kept out of steam boilers, for if allowed to enter serious trouble is almost certain to result. The action of grease in a boiler is peculiar. It does not dissolve in water, it does not decompose, nor, as might be expected does it remain on top of the water. In the presence of heat and the violent ebullition existing in the boiler, it seems to form into what may be termed "slugs" which are of just about the right specific gravity to be carried about in the circulating water. In a short time, however, these slugs or suspended drops seem to acquire a certain degree of stickiness and when they come into contact with the metal surfaces of a boiler they adhere thereto. The ultimate effect is that the whole interior of the boiler becomes "varnished" with a coating of oil. The thinnest possible coating of this varnish is sufficient to bring about overheating of the plates as has been repeatedly found. It is not necessary that this coating be of any appreciable thickness to cause trouble, as it is sufficient to keep the water away from that intimate contact with the metal which is necessary for the quick absorption of the heat.

This coating of oil causes not only overheating of the metal, but is likely to cause leaky tube ends, rivets, seams, in fact, where ever there is a joint. Every possible effort should be made to prevent oil from getting into a boiler, even to the extent of throwing away all hot water which contains any, if no efficient means can be provided for removing the oil before using the water for boiler feed.

An engineer of a cement mill wrote us that every time he opened his Heine Boilers he found the mud drums full of a fine sediment. He asked if we would sanction the removal of the drums in order to avoid the frequent cleanings required. In answering we commented on this evidence of the efficiency of the device and advised him to use the blowoff more frequently.

The Heine mud drum is designed to catch a large proportion of the solids that get into the interior of the boiler with the feed water. Read the description on page 161.

LOSS OF PRESSURE IN PIPES.

There is always a loss of pressure when water flows through pipes. This loss depends on the rate of flow, diameter of pipe and character of the interior surfaces. This loss is further increased by every bend, curve, fitting or valve or anything causing a deviation from a straight line or a change in direction.

The following formula and tables show how such losses can be calculated and thereby allowed for in designing piping.

Weisbach's Formula (Adapted) $P = F \frac{V^2}{2G}$

in which

P = Loss of pressure in pounds per square inch
F = Co-efficient of friction
V = Velocity in feet per second
G = Acceleration of gravity, 32.2

To use the above formula proceed as follows:

Divide the velocity per minute, as found by Table No. 41 for the size of pipe selected and quantity desired, by sixty to reduce to seconds; square the velocity and divide by 64.4; multiply the result by F, as given in Table No. 40, corresponding to the angle of the bend or turn A for which the loss of pressure is desired.

Table No. 41

A. (Angle)	20°	40°	45°	60°	80°	90°	100°	110°	120°	130°
F. (Co-efficient)	0.020	0.060	0.079	0.158	0.320	0.426	0.546	0.674	0.806	0.934

To illustrate the application of the Tables Nos. 40, 41, 42, we give here a concrete example.

Suppose a steam boiler of 100 H. P. capacity, to be supplied with feed water in the usual manner by a feed pump through a heater and pipes.

One boiler horse power = 34.5 lbs of water evaporated per hour from and at 212°F. Any fairly well designed modern plant will deliver its feed water at say 200°F., at which temperature water weighs 60.00 lbs. per cubic foot (Table No. 39). Therefore 34.5 lbs. of water at 60.00 lbs. per cubic foot means 0.575 cubic feet or 4.3 gallons per horse power hour.

Under modern operations it is perhaps more frequent than not that boilers are required to supply for short periods, much more than their

rated power so that it is necessary that provision be made to supply the amount needed without excessive friction losses or pump speeds. Hence the 4.3 gallons should be increased by, say, 75%. Therefore 4.3 gallons $\times 1.75 = 7.53$ gallons per hour. Again, the pipes and fittings may become incrustated or otherwise obstructed so that it is best to increase the amount still further, say to 9 gallons per minute. Therefore we shall need for the 100 H. P. boiler $\frac{9 \text{ gallons} \times 100}{60} = 15$ gallons per minute.

From Table No. 41 we find that a 1¼ in. pipe will deliver 15 gallons per minute with a velocity or rate of flow of 235½ ft. per minute.

Now we will further suppose our boiler to be situated 80 feet distant from the feed pump and that there are six 90° ells, one tee, one angle valve and one globe valve in the line between the pump and the boiler.

The frictions or losses of head will be as below.

For the pipe. In Table No. 42, 15 gallons per minute the loss is 2.38 lbs. × 80 ft.		=	1.904 lbs
For the 6 ells	One 90° turn each by rule above: $235\frac{1}{2} \div 60$	=	3.92 "
For the 1 tee	$3.92 \times 3.92 = 15.37 \div 64.4$	=	0.239 "
For the 1 angle valve	0.239×0.426 (Table No. 40) = 0.1019×8	=	0.815 "
For the 1 globe valve (2−90° bends)	0.1019×2	=	0.204 "
Total friction loss			2.923 lbs
For the difference in level between pump and boiler water level say 8 ft. we have 0.433 lbs. × 8		=	3.464 "
For the boiler pressure say 100 lbs			100 "
Total pressure on pump plunger			106.387 lbs

By Table No. 40 it will be seen that by using two 45° ells effecting the same change in direction as one 90° ell, we make quite a saving as the two 45° ells will only make 37% of the friction made by the one 90° ell, since $\frac{0.239 \times 0.079 \times 2}{0.1019 \times 1} = 37.$

HEATING FEED WATER.

The subject of pre-heating the water intended to be used as feed water for any boiler, above its natural or normal temperature, has two aspects.

First as a matter of safety.

The water in a steam boiler, is at a temperature due to the pressure under which it is working. If the boiler is under a steam pressure of, say 125 lbs. by the gauge, then the water in it will be at a temperature of about 353°F. and a portion of the metal of the boiler is at some higher temperature than this.

Table No. 41

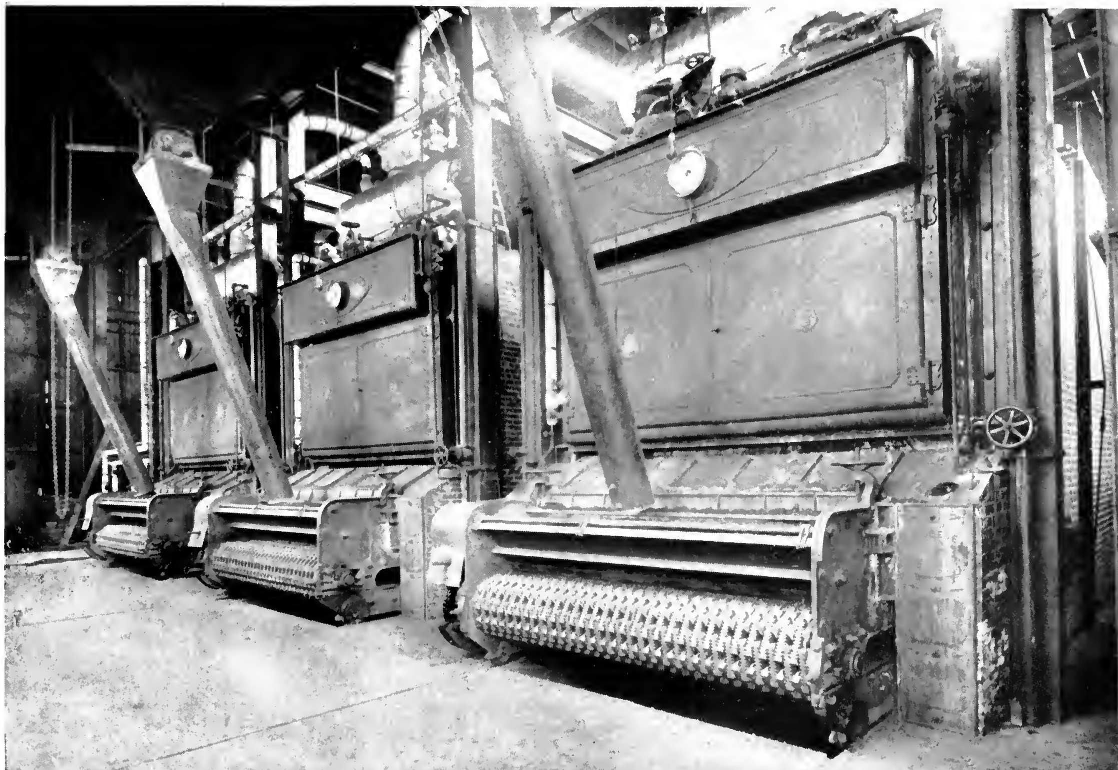
RATE OF FLOW OF WATER, IN FEET PER MINUTE, THROUGH PIPES OF VARIOUS SIZES, FOR VARYING QUANTITIES OF FLOW.

Gallons per min.	Diameter of Pipe							
	¾″	1″	1¼″	1½″	2″	2½″	3″	4″
5	218	122½	78½	54½	30½	19½	13½	7⅔
10	436	245	157	109	61	38	27	15⅓
15	653	367½	235½	163½	91½	58½	40½	23
20	872	490	314	218	122	78	54	30⅔
25	1090	612½	392½	272½	152½	97½	67½	38⅓
30	....	735	451	327	183	117	81	46
35	....	857½	549½	381½	213½	136½	94½	53⅔
40	....	980	628	436	244	156	108	61⅓
45	....	1102½	706½	490½	274½	175½	121½	69
50	....	.....	785	545	305	195	135	76⅔
75	....	.....	1177½	817½	457½	292½	202½	115
100	....	.....	.....	1090	610	380	270	153⅓
125	....	.....	.....	.....	762½	487½	337½	191⅔
150	....	.....	.....	.....	915	585	405	230
175	....	.....	.....	.....	1067½	682½	472½	268⅓
200	....	.....	.....	.....	1220	780	540	306⅔

Table No. 42

LOSS IN PRESSURE DUE TO FRICTION, IN POUNDS PER SQUARE INCH, FOR PIPE 100 FEET LONG.

Gallons per min.	Diameter of Pipe.							
	¾″	1″	1¼″	1½″	2″	2½″	3″	4″
5	3.3	0.84	0.31	0.12	.....	....	....	...
10	13.0	3.16	1.05	0.47	0.12	....	....	....
15	28.7	6.98	2.38	0.97	.....	.....	....	....
20	50.4	12.3	4.07	1.66	0.42	.....	....	....
25	78.0	19.0	6.40	2.62	.....	0.21	0.10	....
30	....	27.5	9.15	3.75	0.91	.....	....	....
35	....	37.0	12.4	5.05	.....	.....	....	....
40	....	48.0	16.1	6.52	1.60	.....	....	....
45	....	.....	20.2	8.15	.....	.....	....	....
50	....	.....	24.9	10.0	2.44	0.81	0.35	0.09
75	....	.....	56.1	22.4	5.32	1.80	0.74	....
100	....	.....	.....	39.0	9.46	3.20	1.31	0.33
125	....	.....	.....	.....	14.9	4.89	1.99	....
150	....	.....	.....	.....	21.2	7.0	2.85	0.69
175	....	.....	.....	.....	28.1	9.46	3.85	....
200	....	.....	.....	.....	37.5	12.47	5.02	1.22



THREE 500 H. P. HEINE BOILERS, ST. LOUIS INDEPENDENT PACKING CO.
EQUIPPED WITH LACLEDE CHRISTY CHAIN GRATES.

The difference in the density or weight of the feed water at, say 70°F. and the water in the boiler at, say 353°F., is such that the colder water when poured into the boiler at once sinks to the bottom, spreading out thereon, and reduces the temperature of the metal structure and as its temperature is raised it commingles with the hotter water. The cold water coming into contact with the very much hotter metal inevitably causes contraction of the metal in its immediate neighborhood, setting up stresses of very uncertain intensity and direction. The effects of such stresses are particularly likely to be manifested in the riveted joints in the shape of cracks, leaks, etc.

That this condition exists in fact is readily demonstrated by an examination of the inspection reports of any of the Boiler Inspection and Insurance Companies.

Secondly as a matter of economy.

Where any of the common methods of water purification are practiced, such as the introduction of chemicals or coagulants into the feed water heater, raising the temperature will, in itself, cause the precipitation of certain of the more common impurities and will also add to and facilitate the action of the chemicals.

Assuming a boiler to operate under a steam pressure of 100 lbs. per square inch, and with feed water at an average temperature of 70°F., the following amount of heat must be supplied to each pound of water to raise its temperature from 70°F. up to 337.89°F. (the boiling point under 100 lbs. pressure) and to evaporate it at that temperature:

In the water at	337.89°F. there are	308.79	B. T. U. above 32°F.
" "	70°F. "	38.06	B. T. U. above 32°F.

Therefore we must add..............270.73 B. T. U. per pound, all of which heat must be supplied by the fuel.

Now, every heat unit which can be saved out of this 270.73 B. T. U., by raising the initial temperature above 70°F., is just that much less to be furnished by the fuel and will reduce the fuel expense accordingly, provided this temperature increase can be obtained without cost.

Except in some particular lines of industry there is usually a surplus of exhaust steam, the heat of which may with great economy, be used for heating the feed water.

In some large municipal heating plants, in some industries in which the drying of material is extensive, or in plants for manufacturing distilled water or ice, it may happen that the exhaust steam from the engines and pumps can be used more economically for purposes other than

FIVE 300 H. P. HEINE BOILERS, POLAR WAVE ICE AND FUEL CO., ST. LOUIS, MO., EQUIPPED WITH LACLEDE CHRISTY CHAIN GRATES.

for heating the feed water. In such cases a heater in the smoke flue or a live steam purifier may be advisable.

When flue heaters are used they are styled economizers, and in cases where the boilers are overworked to such an extent that it is necessary, in order to obtain the desired amount of power, for the flue gases to escape from the boilers into the chimney at a temperature higher than may be necessary to maintain the draft, and where the floor space for more boilers is not obtainable, economizers are a valuable and efficient adjunct. They permit the feed water to be raised to a temperature much higher than is ever possible with an exhaust steam heater. Sometimes, on the other hand where the flue gases are at a temperature only high enough to create a sufficient draft, and where therefore economizers are not advisable, live steam purifiers may be used.

Such devices are usually placed at a higher elevation than the boilers and are connected directly into or with the steam space of the boilers themselves, and are therefore under the same steam pressure. The feed water is quite frequently pumped out of or through an exhaust steam heater where it receives such heat as may be available, directly into the purifier, from which it passes into the boilers by gravity. In such cases economizers may be used if the draft is maintained by some sort of mechanical draft apparatus.

By all the devices mentioned the feed water is raised to a temperature at which no harm to the boiler is to be anticipated, and the effect of any purifying effort which may be attempted is much increased, due to the increase in temperature.

There is, however, little, if any, economy of fuel to be expected from the use of purifiers, but the elimination of the destructive stresses and the additional purifying effect may be considered as ample repayment for the extra cost of the apparatus.

Economizers, on the other hand, where conditions are such as to permit of their use, result in a saving of fuel directly in proportion to the rise in temperature effected.

The possible economy of fuel which may be expected to result from any increase in the initial temperature of the feed water may be readily ascertained by the use of the following formula:

$$\frac{100\,(T-t)}{H-t} = \text{percentage of resulting saving.}$$

In which T = B. T. U. in water above 32°F. after passing through heater.
t = B. T. U. " " 32°F. before passing through heater.
H = B. T. U. in steam above 32°F. at boiler pressure.

To illustrate, suppose that in the case mentioned above the natural temperature of the water is 60°F., and that by passing it through an efficient heater supplied with exhaust steam, its temperature is raised to 210°F., we should have

$$\frac{100\,(177.99 - 28.08)}{1188.77 - 28.08} = 12.91\% \text{ saving in fuel.}$$

FEED WATER HEATERS.

Feed water heaters are of two general styles known as the open and the closed or pressure heaters. In the open heater the water is fed by gravity or by city pressure into a vessel through which it passes slowly and in thin streams or sheets over a number of pans in succession, dripping from one into the next while it is exposed to the heat of the exhaust steam. After being heated, it flows by gravity into the suction of the boiler feed pump. In this type no pressure exists excepting possibly a small back pressure of one or two pounds, and hence such heaters are designed to withstand only about thirty pounds pressure. They are built of both cast iron and sheet metal or steel.

The closed heater consists essentially of a shell made heavy enough to withstand the boiler pressure, provided with an arrangement of tubes of brass or steel. The feed water, fed by the pump, passes through the heater either inside or around the tubes and is heated by exhaust steam on the other side of the tubes. In the open heater, the water comes in direct contact with the steam, while in the closed heater the two are separated by metal walls.

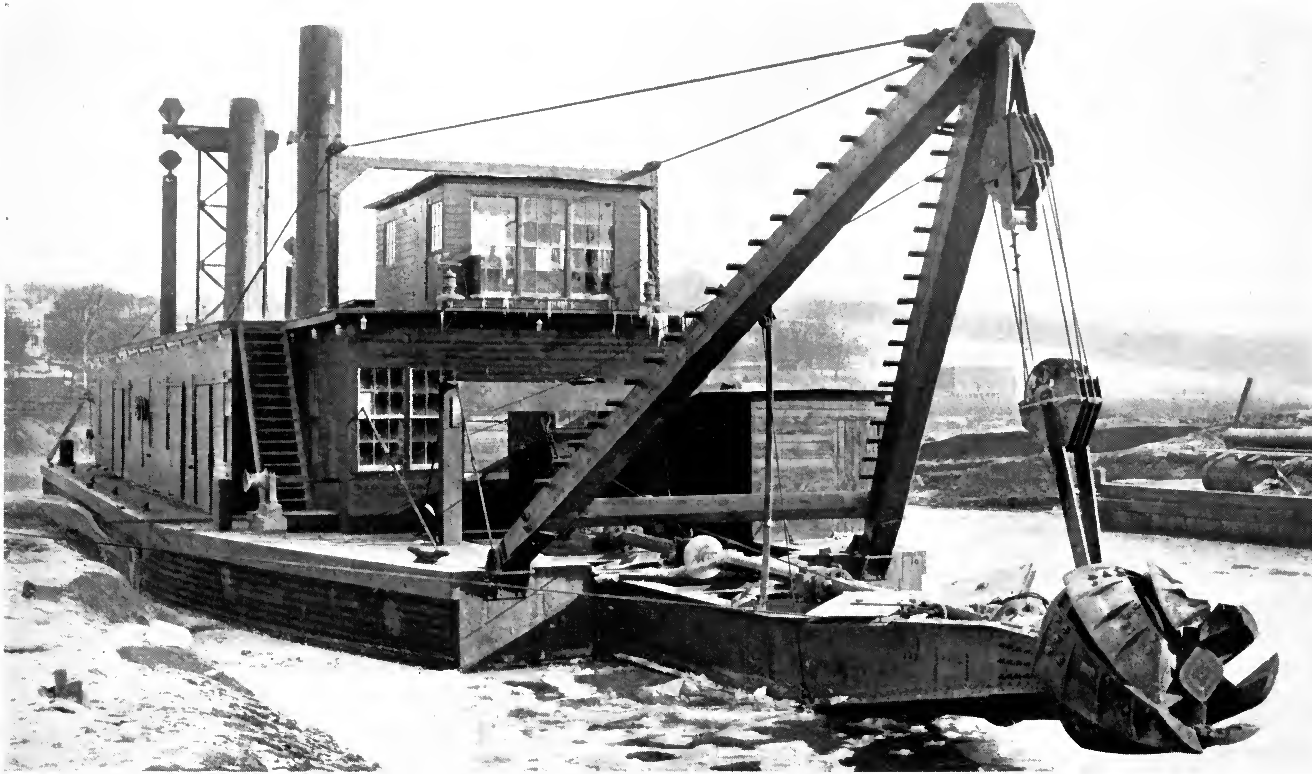
The most common and serious error made in the selection of a feed water heater for any plant is in getting one of too small a size. Any heater whether open or closed should be of ample capacity. In too small a heater the velocity of the water passing through it is so great the impurities which may have been made insoluble have not the time and space in which to settle, nor will the water be heated to as high a temperature as in a heater of proper size.

Aside from acting as a receptacle for solid deposits, the Heine mud drum performs the additional function of preventing cold feed water from coming into contact with the metal structure of the boiler, until after it has been heated sufficiently to avoid any of the consequences outlined at the top of page 89. The reasons for this may be found on page 161.

Table No. 43.

PERCENTAGE OF SAVING IN FUEL BY HEATING FEED-WATER. STEAM AT 70 POUNDS GAUGE PRESSURE.

Initial Temperature of Feed	TEMPERATURE TO WHICH FEED IS HEATED														
	100	110	120	130	140	150	160	170	180	190	200	210	220	250	300
35°	5.50	6.35	7.19	8.04	8.89	9.73	10.57	11.42	12.28	13.13	13.97	14.83	15.68	18.26	22.59
40°	5.10	5.95	6.80	7.65	8.49	9.34	10.20	11.05	11.90	12.75	13.61	14.46	15.32	17.91	22.26
45°	4.69	5.54	6.40	7.25	8.11	8.96	9.81	10.67	11.52	12.38	13.24	14.10	14.96	17.56	21.93
50°	4.28	5.14	5.99	6.85	7.71	8.57	9.42	10.28	11.14	12.00	12.86	13.73	14.59	17.21	21.59
55°	3.87	4.73	5.59	6.45	7.38	8.17	9.03	9.90	10.76	11.62	12.49	13.35	14.22	16.85	21.25
60°	3.45	4.31	5.18	6.04	6.91	7.77	8.64	9.51	10.37	11.24	12.11	12.97	13.85	16.49	20.91
65°	3.03	3.90	4.77	5.64	6.50	7.37	8.24	9.11	9.98	10.86	11.73	12.60	13.48	16.12	20.57
70°	2.60	3.48	4.35	5.23	6.10	6.97	7.84	8.72	9.57	10.46	11.35	12.22	13.10	15.76	20.22
75°	2.18	3.06	3.94	4.82	5.69	6.56	7.44	8.32	9.19	10.08	10.96	11.83	12.72	15.39	19.87
80°	1.76	2.64	3.51	4.39	5.27	6.15	7.03	7.91	8.80	9.68	10.56	11.45	12.34	15.02	19.52
85°	1.32	2.21	3.09	3.97	4.85	5.74	6.62	7.51	8.39	9.28	10.17	11.06	11.95	14.64	19.17
90°	0.88	1.77	2.66	3.55	4.43	5.32	6.21	7.10	7.99	8.88	9.77	10.67	11.56	14.26	18.81
95°	0.44	1.34	2.23	3.12	4.01	4.90	5.79	6.68	7.58	8.47	9.37	10.27	11.17	13.89	18.45
100°	0.09	0.89	1.79	2.68	3.58	4.47	5.37	6.27	7.17	8.06	8.97	9.87	10.77	13.50	18.08



20-INCH HYDRAULIC DREDGE, NEW YORK BARGE CANAL, FITTED WITH 700 H. P. OF HEINE BOILERS.

STEAM.

WHEN water is heated in an open vessel its temperature rises until it reaches 212°F. (at sea level); if more heat is added a portion of the water changes from a liquid form to a vapor called *steam*. If the process is carried on in a closed vessel the pressure within rises on account of the expansive force of the steam. The water then will rise to a higher temperature with each increment of pressure before it begins to boil and form steam.

For the distinction between "sensible" and "latent" heat see P. 10

Table No. 44, giving the properties of saturated steam, is adapted from Marks and Davis' Tables of the Properties of Saturated Steam. The first column gives the actual pressure in pounds per square inch above a vacuum.

Column two gives the temperature in degrees Fahrenheit for the corresponding pressure.

Columns three and four give the volume of one pound in cubic feet and the weight of one cubic foot of saturated steam.

Column five gives the heat, in heat units, of the water above 32°F.

Column six gives the heat of vaporization for the corresponding pressure, i. e., the heat rendered latent in the transformation from water to steam.

WASHBURN CROSBY FLOUR MILLS, MINNEAPOLIS, MINN., CONTAINS 7000 H. P. OF HEINE BOILERS.

Column seven gives the total heat in the steam above 32°F. and is the sum of columns five and six.

Table No. 44

PROPERTIES OF SATURATED STEAM.
FROM MARKS AND DAVIS' TABLES.

1 Gauge Pressure in lbs. per sq. in. P	2 Temp. Degrees F	3 Sp. Vol. Cu. Ft. per lb. V or S	4 Density lbs. per Cu. Ft. V	5 Heat of the liquid Q	6 Latent heat of Evap. L or R	7 Total Heat of Steam H	8 Gauge Pressure in lbs. per sq. in. P
1	101.83	333.0	0.00300	69.8	1034.6	1104.4	1
2	126.15	173.5	0.00576	94.0	1021.0	1115.0	2
3	141.52	118.5	0.00845	109.4	1012.3	1121.6	3
4	153.01	90.5	0.01107	120.9	1005.7	1126.5	4
5	162.28	73.33	0.01364	130.1	1000.3	1130.5	5
6	170.06	61.89	0.01616	137.9	995.8	1133.7	6
7	176.85	53.56	0.01867	144.7	991.8	1136.5	7
8	182.86	47.27	0.02115	150.8	988.2	1139.0	8
9	188.27	42.36	0.02361	156.2	985.0	1141.1	9
10	193.22	38.38	0.02606	161.1	982.0	1143.1	10
14.7	212.00	26.79	0.03732	180.0	970.4	1150.4	14.7
20	228.00	20.08	0.04980	196.1	960.0	1156.2	20
25	240.10	16.30	0.0614	208.4	952.0	1160.4	25
30	250.30	13.74	0.0728	218.8	945.1	1163.9	30
35	259.3	11.89	0.0841	227.9	938.9	1166.8	35
40	267.3	10.49	0.0953	236.1	933.3	1169.4	40
45	274.5	9.39	0.1065	243.4	928.2	1171.6	45
50	281.0	8.51	0.1175	250.1	923.5	1173.6	50
55	287.1	7.78	0.1285	256.3	919.0	1175.4	55
60	292.7	7.17	0.1394	262.1	914.9	1177.0	60
65	298.0	6.65	0.1503	267.5	911.0	1178.5	65
70	302.9	6.20	0.1612	272.6	907.2	1179.8	70
75	307.6	5.81	0.1721	277.4	903.7	1181.1	75
80	312.0	5.47	0.1829	282.0	900.3	1182.3	80
85	316.3	5.16	0.1937	286.3	897.1	1183.4	85
90	320.3	4.89	0.2044	290.5	893.9	1184.4	90
95	324.1	4.65	0.2151	294.5	890.9	1185.4	95
100	327.8	4.429	0.2258	298.3	888.0	1186.3	100
105	331.4	4.230	0.2365	302.0	885.2	1187.2	105
110	334.8	4.047	0.2472	305.5	882.5	1188.0	110
115	338.1	3.880	0.2577	309.0	879.8	1188.8	115
120	341.3	3.726	0.2683	312.3	877.2	1189.6	120
125	344.4	3.583	0.2791	315.5	874.7	1190.3	125
130	347.4	3.452	0.2897	318.6	872.3	1191.0	130
135	350.3	3.331	0.3002	321.7	869.9	1191.6	135
140	353.1	32.19	0.3107	324.6	876.6	1192.2	140
145	355.8	3.112	0.3213	327.4	865.4	1192.8	145
150	358.5	3.012	0.3320	330.2	863.2	1193.4	150
155	361.0	2.920	0.3425	332.9	861.4	1193.8	155
160	363.6	2.834	0.3529	335.6	858.8	1194.5	160
165	366.0	2.753	0.3633	338.2	856.8	1195.0	165
170	368.5	2.675	0.3738	340.7	854.7	1195.4	170
175	370.8	2.602	0.3843	343.2	852.7	1195.9	175
180	373.1	2.533	0.3948	345.6	850.8	1196.4	180
185	375.4	2.468	0.4052	348.0	848.8	1196.8	185

The ratio of the heat necessary to evaporate one pound of water under actual conditions of feed temperature and steam pressure to the heat required to evaporate one pound from and at 212°F. (which is at atmospheric pressure at sea level) is called the factor of evaporation. The heat necessary to evaporate one pound of water from and at 212°F. is 970.4 B. T. U.

From table No. 45 may be obtained the factors of evaporation for a wide range of conditions.

Table No. 45

FACTORS OF EVAPORATION.

Temp. Feed	Gauge Pressure																
	40	50	60	70	80	90	100	110	120	130	140	150	160	170	170	180	190
32	1.212	1.215	1.218	1.220	1.223	1.224	1.226	1.227	1.229	1.230	1.231	1.232	1.233	1.234	1.235	1.236	1.236
35	1.209	1.212	1.215	1.217	1.220	1.221	1.223	1.224	1.225	1.227	1.228	1.229	1.230	1.231	1.232	1.232	1.233
40	1.203	1.207	1.209	1.212	1.214	1.216	1.217	1.219	1.220	1.221	1.223	1.224	1.225	1.226	1.226	1.227	1.228
45	1.198	1.201	1.204	1.207	1.209	1.210	1.212	1.214	1.215	1.216	1.217	1.218	1.219	1.220	1.221	1.222	1.223
50	1.193	1.196	1.199	1.201	1.204	1.205	1.207	1.209	1.210	1.211	1.212	1.213	1.214	1.215	1.216	1.217	1.218
55	1.188	1.191	1.194	1.196	1.199	1.200	1.202	1.203	1.205	1.206	1.207	1.208	1.209	1.210	1.211	1.212	1.213
60	1.183	1.186	1.189	1.191	1.194	1.195	1.197	1.198	1.200	1.201	1.202	1.203	1.204	1.205	1.206	1.207	1.207
65	1.178	1.181	1.184	1.186	1.189	1.190	1.912	1.193	1.194	1.196	1.197	1.198	1.199	1.200	1.201	1.201	1.202
70	1.172	1.176	1.178	1.181	1.183	1.185	1.186	1.188	1.189	1.190	1.192	1.193	1.194	1.195	1.196	1.196	1.197
75	1.167	1.170	1.173	1.176	1.178	1.118	1.181	1.183	1.184	1.185	1.186	1.187	1.188	1.189	1.190	1.191	1.192
80	1.162	1.165	1.168	1.170	1.173	1.174	1.176	1.177	1.179	1.180	1.181	1.182	1.183	1.184	1.185	1.186	1.187
85	1.157	1.160	1.163	1.165	1.168	1.169	1.171	1.172	1.174	1.175	1.176	1.177	1.178	1.179	1.180	1.181	1.182
90	1.152	1.155	1.158	1.160	1.163	1.164	1.166	1.167	1.168	1.170	1.171	1.172	1.173	1.174	1.175	1.176	1.176
95	1.147	1.150	1.153	1.155	1.158	1.159	1.161	1.162	1.163	1.165	1.166	1.167	1.168	1.169	1.170	1.170	1.171
100	1.142	1.145	1.147	1.150	1.153	1.154	1.156	1.157	1.158	1.160	1.161	1.162	1.163	1.164	1.164	1.165	1.166
105	1.136	1.140	1.142	1.145	1.147	1.149	1.150	1.152	1.153	1.154	1.156	1.157	1.158	1.159	1.160	1.160	1.161
110	1.131	1.134	1.137	1.140	1.142	1.144	1.145	1.147	1.148	1.149	1.150	1.151	1.152	1.153	1.154	1.155	1.156
115	1.126	1.129	1.132	1.134	1.137	1.138	1.140	1.141	1.143	1.144	1.145	1.146	1.147	1.148	1.149	1.150	1.151
120	1.121	1.124	1.127	1.129	1.132	1.133	1.135	1.136	1.138	1.139	1.140	1.141	1.142	1.143	1.144	1.145	1.146
125	1.116	1.119	1.122	1.124	1.127	1.128	1.130	1.131	1.132	1.134	1.135	1.136	1.137	1.138	1.139	1.140	1.140
130	1.111	1.114	1.116	1.119	1.122	1.123	1.125	1.126	1.127	1.129	1.130	1.131	1.132	1.133	1.134	1.135	1.135
135	1.105	1.109	1.111	1.114	1.116	1.118	1.119	1.121	1.122	1.123	1.125	1.126	1.127	1.128	1.129	1.129	1.130
140	1.100	1.104	1.106	1.109	1.111	1.112	1.114	1.116	1.117	1.118	1.120	1.121	1.122	1.123	1.123	1.124	1.125
145	1.095	1.098	1.101	1.103	1.106	1.107	1.109	1.111	1.112	1.113	1.114	1.115	1.116	1.117	1.118	1.119	1.120
150	1.090	1.093	1.096	1.098	1.101	1.102	1.104	1.105	1.107	1.108	1.109	1.110	1.111	1.112	1.113	1.114	1.115
155	1.085	1.088	1.091	1.093	1.096	1.097	1.099	1.100	1.102	1.103	1.104	1.105	1.106	1.107	1.108	1.109	1.110
160	1.080	1.083	1.086	1.088	1.091	1.092	1.094	1.095	1.096	1.098	1.099	1.100	1.101	1.102	1.193	1.104	1.104
165	1.074	1.078	1.080	1.083	1.085	1.087	1.088	1.090	1.091	1.092	1.094	1.095	1.096	1.097	1.098	1.098	1.099
170	1.069	1.073	1.075	1.078	1.080	1.082	1.083	1.085	1.086	1.087	1.088	1.090	1.091	1.092	1.092	1.093	1.094
175	1.064	1.067	1.070	1.072	1.075	1.076	1.078	1.079	1.081	1.082	1.083	1.084	1.085	1.086	1.087	1.088	1.089
180	1.059	1.062	1.065	1.067	1.070	1.071	1.073	1.074	1.076	1.077	1.078	1.079	1.080	1.081	1.082	1.083	1.084
185	1.054	1.057	1.060	1.062	1.065	1.066	1.068	1.069	1.070	1.072	1.073	1.074	1.075	1.076	1.077	1.078	1.079
190	1.049	1.052	1.055	1.057	1.060	1.061	1.063	1.064	1.065	1.066	1.068	1.069	1.070	1.071	1.072	1.073	1.073
195	1.043	1.046	1.049	1.051	1.055	1.056	1.058	1.059	1.060	1.062	1.063	1.064	1.065	1.066	1.067	1.067	1.068
200	1.038	1.041	1.044	1.047	1.049	1.051	0.052	1.054	1.055	1.056	1.057	1.058	1.059	1.060	1.061	1.062	1.063
205	1.033	1.036	1.039	1.041	1.044	1.045	1.047	1.049	1.050	1.051	1.052	1.053	1.054	1.055	1.056	1.057	1.058
210	1.028	1.031	1.034	1.036	1.039	1.040	1.042	1.043	1.045	1.046	1.047	1.048	1.049	1.050	1.051	1.052	1.053
212	1.026	1.029	1.032	1.034	1.037	1.038	1.040	1.041	1.043	1.044	1.045	1.046	1.047	1.048	1.049	1.050	1.051

SUPERHEATED STEAM.

In the use of steam in a steam engine one of the largest losses which occurs is that of the initial condensation, due to the contact of the hot steam with the comparatively cool surfaces of the cylinder head, piston head, and cylinder walls. For many years the only effort to diminish this loss took the form of a multiplication of cylinders; but this remedy though reducing the loss did not cure the trouble. It was argued that if the temperature of the steam could be raised above that due to its pressure, the expenditure of this extra heat would result in a benefit if it prevented the initial cylinder condensation.

Mr. Basil Dixon made some exhaustive experiments upon the boilers of a steamer belonging to the United States Government which seemed to give promise of great possible economies. Later, similar experiments were made by the late Mr. Isherwood, Chief Engineer of the United States Navy, the results of which substantiated those previously obtained by Mr. Dixon, and ever since, the subject of superheating steam has been a most interesting and fascinating one and numberless experiments have been made with a view of bringing it into common use.

While, however, the resulting economies were large, difficulties arose which for many years were very baffling. The lubrication of the cylinders at the high temperature due to the superheat, was found to be very difficult; piston and rod packings, as well as gaskets in flange joints, quickly burned out and many mysterious accidents occurred in valves and fittings, due, it was supposed to the use of improper materials. Very many of these troubles have now, however, been almost entirely overcome. The question of lubrication is handled satisfactorily if only a moderate amount of superheat is used. Metallic rod packings have replaced the use of others, and metallic gaskets have cured the troubles with flanges and flanged joints. So far as material for valves and fittings is concerned, the opinion seems to have crystallized now into the idea that if the excessive expansion due to the high temperatures is properly provided for these troubles will largely disappear, especially if heavier fittings of cast steel are used instead of cast iron. There is but little doubt that many of the previous troubles and accidents, attributed at the time to the high temperatures of the steam, were due in fact to the increased expansion of the linings and in many cases to failures of fittings due to defects which were not previously suspected.

It remains yet to be demonstrated to just what extent superheating may be carried with benefit, but conservative engineers have quite commonly arrived at the opinion that 100° to 125° superheat is about the limit to which superheating may be carried satisfactorily from all points

of view, considering on the one hand the increased engine economy and on the other not too great an increase in the initial expense and cost of maintenance. It is, however, quite natural to believe that the above named limit will be raised much higher as the use of superheated steam increases and the limiting features become more definitely understood.

PROPERTIES OF SUPERHEATED STEAM.

The total heat in superheated steam is represented by the equation

$$H_t = H + C_p (T_s - T)$$

Where H = the total heat above 32°F. in saturated steam at the given pressure

C_p = the specific heat of the superheated steam,

T_s = the temperature of the superheated steam,

T = temperature of the saturated steam.

In the older works on superheated steam the value of Cp was assumed to be a constant and equal to .48. Later experiments have shown this value to be incorrect and that the specific heat varies both with the pressure and with the degree of superheat. In general, it is found that the specific heat increases with the increase of pressure and decreases with the increase of temperature.

The following tables are arranged from the results of Professor Knoblauch and Dr. Jakob published in the Zeitschrift des Vereins Deutscher Ingenieure and of Professor Thomas and Mr. Short published in the Transactions of the American Society of Mechanical Engineers, Vol. 29.

Table No. 46

SPECIFIC HEAT OF SUPERHEATED STEAM.
Knoblauch and Jakob

Degrees (F) of Superheat	Pressure in lbs. per sq. in. (absolute)									
	5	15	25	50	75	100	150	200	250	300
10	0.460	0.470	0.480	0.509	0.540	0.570	0.620	0.690	0.770	0.850
50	0.460	0.470	0.479	0.504	0.528	0.550	0.592	0.634	0.678	0.724
100	0.459	0.469	0.477	0.498	0.517	0.534	0.562	0.590	0.615	0.641
150	0.459	0.469	0.476	0.494	0.509	0.522	0.544	0.563	0.582	0.599
200	0.460	0.468	0.476	0.491	0.504	0.515	0.533	0.548	0.562	0.576
250	0.460	0.468	0.475	0.489	0.500	0.509	0.524	0.537	0.549	0.561
300	0.460	0.468	0.475	0.487	0.497	0.505	0.518	0.529	0.540	0.550

FEDERAL ST. STATION, PA. R. R. CO., ALLEGHENY, PA., CONTAINS 224 H. P. OF HEINE BOILERS.

Table No. 47

SPECIFIC HEAT OF SUPERHEATED STEAM.

Thomas and Short

Degrees (F) of Superheat	Pressure in lbs. per sq. in. (absolute)							
	5	15	40	60	100	150	300	600
50	0.519	0.530	0.555	0.569	0.587	0.600	0.619	
100	0.497	0.507	0.528	0.539	0.557	0.571	0.589	0.608
150	0.488	0.496	0.515	0.526	0.543	0.557	0.574	0.591
200	0.484	0.491	0.508	0.518	0.533	0.545	0.561	0.578
250	0.481	0.488	0.503	0.512	0.525	0.535	0.551	0.567
300	0.480	0.486	0.498	0.506	0.515	0.527	0.540	0.556

Example. Required the total heat above 32°F. in a pound of steam at 100 lbs. per sq. in. pressure above a vacuum and with 100°F. of superheat.

From Table No. 44, page 96 of Properties of Saturated Steam, we find that one pound of saturated steam at 100 pounds per sq. in. pressure contains 1186.3 B. T. Us. From Table No. 46, page 99, Specific Heat of Superheated Steam, we find the specific heat of superheated steam at 100 lbs. per sq. in. pressure and 100°F. of superheat to be 0.534. Then the heat required to superheat one lb. of the steam will be $0.534 \times 100° = 53.4$ B. T. U's.

Total heat above 32°F. $= 1186.3 + 53.4 = 1239.7$ B. T. U's.

To find the factor of evaporation of steam superheated 100°F., if the feed water temperature is taken as 170°F., proceed as follows: From Table No. 44, page 96, Properties of Saturated Steam, the heat of the liquid of water at 60°F. is found to be 169.9 B. T. U's. Subtract this amount from the total heat above 32°F. of the superheated steam (1239.7) and divide the remainder by 970.4, the latent heat of evaporation of steam at 212°F. The quotient will be the factor of evaporation required.

$$\frac{1239.7 - 169.9}{970.4} = 1.102$$

THE MOTION OF STEAM.

The flow of steam under pressure into an atmosphere of a less pressure, increases as the difference of pressure is increased, until the external pressure becomes only 58 per cent of the absolute pressure in the boiler. The flow of steam is neither increased nor diminished by the fall

of the external pressure below 58 per cent, or about $\frac{4}{7}$ of the inside pressure, even to the extent of a perfect vacuum. In flowing through a nozzle of the best form, the steam expands to the external pressure, and to the volume due to this pressure, so long as it is not less than 58 per cent of the internal pressure. For an external pressure of 58 per cent, and for lower percentages, the ratio of expansion is 1 to 1.624. The following table, No. 48, is selected from Mr. Brownlee's data exemplifying the rates of discharge, under a constant internal pressure, into various external pressures:

Table No. 48

OUTFLOW OF STEAM; FROM A GIVEN INITIAL PRESSURE INTO VARIOUS LOWER PRESSURES.

D. K. C.

Absolute Pressure in Boiler in Lbs. Per Square Inch.	External Pressure in Lbs. per Square Inch	Ratio of Expansion in Nozzle	Velocity of Outflow at Constant Density.	Actual Velocity of Outflow, Expanded.	Discharge per Square Inch of Orifice per Minute.
Lbs.	Lbs.	Ratio	Ft. per Sec.	Ft. per Sec.	Lbs.
75	74	1.012	227.5	230.	16.68
75	72	1.037	386.7	401.	28.35
75	70	1.063	490.	521.	35.93
75	65	1.136	660.	749.	48.38
75	61.62	1.98	736.	876.	53.97
75	60	1.219	765.	933.	56.12
75	50	1.434	873.	1252.	64.
75	45	1.575	890.	1401.	65.24
75	13.46 (58%)	1.624	890.6	1446.5	65.3
75	15	1.624	890.6	1446.5	65.3
75	0	1.624	890.6	1446.5	65.3

HOTEL VAN NUYS, LOS ANGELES, CAL.
CONTAINS 200 H. P. OF HEINE BOILERS.

When, on the contrary, steam of varying initial pressure is discharged into the atmosphere—pressures of which the atmospheric pressure is not more than 58 per cent—the velocity of outflow at constant density, that is, supposing the initial density to be maintained, is given by the formula—

$$V = 3.5953 \sqrt{h}$$

where V = the velocity of outflow in feet per minute, as for steam of the initial density. h = the height in feet of a column of steam of the given absolute initial pressure of uniform density, the weight of which is equal to the pressure on the unit of base.

The following table is calculated from this formula.

Table No. 49

OUTFLOW OF STEAM INTO THE ATMOSPHERE.

D. K. C.

Absolute Initial Pressure in Pounds per Square Inch.	External Pressure in Pounds per Square Inch.	Ratio of Expansion in Nozzle.	Velocity of Outflow at Constant Density.	Actual Velocity of Outflow, Expanded.	Discharge per Square Inch of Orifice per Min.
Lbs.	Lbs.	Ratio.	Ft. per Sec.	Ft. per Sec.	Lbs.
25.37	14.7	1.624	863	1401	22.81
30	14.7	1.624	867	1408	26.84
40	14.7	1.624	874	1419	35.18
45	14.7	1.624	877	1424	39.78
50	14.7	1.624	880	1429	44.06
60	14.7	1.624	885	1437	52.59
70	14.7	1.624	889	1444	61.07
75	14.7	1.624	891	1447	65.30
90	14.7	1.624	895	1454	77.94
100	14.7	1.624	898	1459	86.34
115	14.7	1.624	902	1466	98.76
135	14.7	1.624	906	1472	115.61
155	14.7	1.624	910	1478	132.21
165	14.7	1.624	912	1481	140.46
215	14.7	1.624	919	1493	181.58

CONDENSATION OF STEAM IN PIPES.

When steam pipes are exposed to a temperature less than that of the steam within, condensation takes place more or less rapidly, according to the condition of the surfaces and the temperature and rate of motion of the surrounding medium.

Experiments made by different parties in still air gave the following results.

Table No. 51

CONDENSATION IN UNCOVERED PIPES.

OBSERVER	Difference of Temperature of Steam and Air	Steam Condensed per Square Foot per Hour, per 1°F	B. T. U. Lost per Square Foot per Hour, per 1°F
Tregold	161°F.	0.0022 lb.	2.100
Burnat	196.6°F.	0.0030 lb.	2.864
Clement	151°F.	0.00217 lb.	2.071
Grouvelle	168°F.	0.0020 lb.	1.909
Average for steam of 20 lbs. absolute pressure	169°F.	0.00235 lb.	2.236

We further give an abstract of the results of a careful series of tests made by Mr. George M. Brill, M. E., in 1895, with the best modern coverings, and with the most accurate instruments. The steam pressure carried ran between 110 and 119 lbs. per square inch, and the temperature of the air varied from 50° to 81°F. in the various tests.

For the purposes of these tests about 60 feet of standard 8-inch wrought pipe, coupled together, in order to make it smooth and regular, was suspended where it could not be subjected to currents of air. In order to get the steam as dry as possible it was sent through a separator on its way to the test pipe, and in the short connection between the separator and the pipe was placed a throttling calorimeter. The test pipe had an inclination of one foot in its entire length, which insured drainage of all the water of condensation to the lower end, at which point the receiver was connected, and into which the water gravitated as rapidly as formed. The water was measured in this receiver, which consisted of four feet of 12-inch pipe, with graduated water glasses attached near the top and bottom. The same volume of water was allowed to collect each time, was measured under the steam pressure, and blown from the receiver at the end of the run. A careful determination was made of the amount of water collected by weighing the same volume while cold, and correcting for difference in weight due to the difference in temperature for the respective runs.

The tests were made upon a scale large enough—in fact, upon a pipe of the size and length which is very common in the average power plant—with sufficient care, and in a manner to insure accuracy in the results obtained, and are consequnetly of much interest and value to all users of steam.

The results reduced to the proper units are given in Table No. 52 below, and may be taken as fairly representative of the best modern practice. Of course, whenever steam pipes are placed where they are ex-

posed to currents of air, the amount of condensation will be some greater than the tabular numbers.

This table also gives the saving in pounds of steam, and in dollars and cents due to the use of coverings. This saving is based on the assumption that coal costs $2.44 per ton, and adding 12 per cent for cost of firing, and taking 7 lbs. water per lb. of coal as an evaporative figure, which are rough approximations to average American conditions.

Table No. 52

SHOWING RADIATION DUE TO BARE AND COVERED PIPES, AND SAVING DUE TO COVERINGS.

KINDS OF COVERING	B. T. U. Transmitted per Hour per Square Foot Pipe per Degree Difference in Temperature	Lbs. Steam Condensed per Hour per Square Foot Pipe per Degree Difference in Temperature	Lbs. Steam Saved per 100 Square Feet Pipe per Year	Saving in Dollars per 100 Square Feet Pipe per Year
Bare Pipe	2.7059	.003107	....	....
Magnesia	.3838	.000432	635,801	$110.82
Rock Wool	.2556	.000285	670,666	116.90
Mineral Wool	.2846	.000311	662,957	115.55
Fire Felt	.5023	.000591	603,389	105.17
Manville Sectional	.3496	.000409	645,174	112.45
Manville Sectional and Hair Felt	.2119	.000243	682,930	119.03
Manville Wool Cement	.3448	.000410	646,488	112.68
Champion Mineral Wool	.3166	.000364	654,197	114.03
Hair Felt	.4220	.000472	625,376	109.00
Riley Cement	.9531	.001089	479,960	83.66
Fossil Meal	.8787	.001010	500,284	87.20

The presence of sulphur in the best coverings and its recognized injurious effects, makes it imperative that moisture must be kept from the coverings, for if present, will surely combine with the sulphur, thus making it active. This could be stated in other words, *keep the pipes and covering in good repair.* Much of the inefficiency of coverings is due to the lack of attention given them; they are often seen hanging loosely from the pipe which they are supposed to protect.

All coverings should be looked after at least once a year and given necessary repairs, refitted to the pipe, the spaces due to shrinkage taken up, for little can be expected from the best non-conductors if they are allowed to become saturated with water, or if air currents are permitted to circulate between them and the pipe.

OLD NATIONAL BANK BUILDING, SPOKANE, WASH.
CONTAINS 500 H P. OF HEINE BOILERS.

As a very rough approximation we may say that each 10 square feet of uncovered pipe will condense, in winter, 105 lbs. of steam during a day of ten hours. Under the same conditions, the same pipe protected with the best covering will condense approximately 8. lbs. steam.

In summer these figures will be reduced respectively to 80 lbs. and 6½ lbs. of steam.

Moisture in steam at the end of a long pipe line is often erroneously attributed to priming of the boiler; whereas, it is really due to condensation. The amount of steam condensed is really but a very small proportion of the total steam passing through the pipe, but gradually collecting at some point in the line, it is carried along in a body at intervals, producing the effects of entrained water.

Mr. Henry G. Stott, Supt. M. P., I. R. T. Co., New York, conducted a series of tests to determine the relative efficiencies of pipe coverings. His method consisted in coupling up about two hundred feet of two-inch iron pipe in three lines and mounting them on wooden horses about three and one-half feet from the floor, the three lines of pipe being approximately four feet apart and four feet from the nearest wall, in order to avoid any errors due to heat convection and radiation.

Sections fifteen feet in length were marked off on the straight portions of the pipe, and so arranged as not to include any pipe couplings or bends; two feet from each end of each section heavy potential wires were soldered on to the pipe, and at the extreme end of the pipe 1,500,000 c. m. copper insulated cables were soldered on, the openings in the pipe having been previously closed by means of a standard coupling and plug. One of these cables ran direct to one terminal of a 250 K. W., 250 volt steam driven, direct coupled exciter, which was solely devoted to furnishing current for the test, and which could have its voltage varied within wide limits so as to furnish any current up to one thousand five hundred amperes. The cable connected to the other end of the pipe was then connected to three ammeter shunts in series, in order to enable the readings to be easily checked, after which it was carried through a circuit breaker and switch to the other exciter terminal.

The method of testing was to put a current of sufficient quantity through the pipe to heat it to say two hundred and twenty degrees F., and keep this current on for a sufficient length of time to enable all sections to maintain a constant temperature (this period was found to be about ten hours) when readings of the milli-volt-meter were taken on each section with simultaneous ammeter readings.

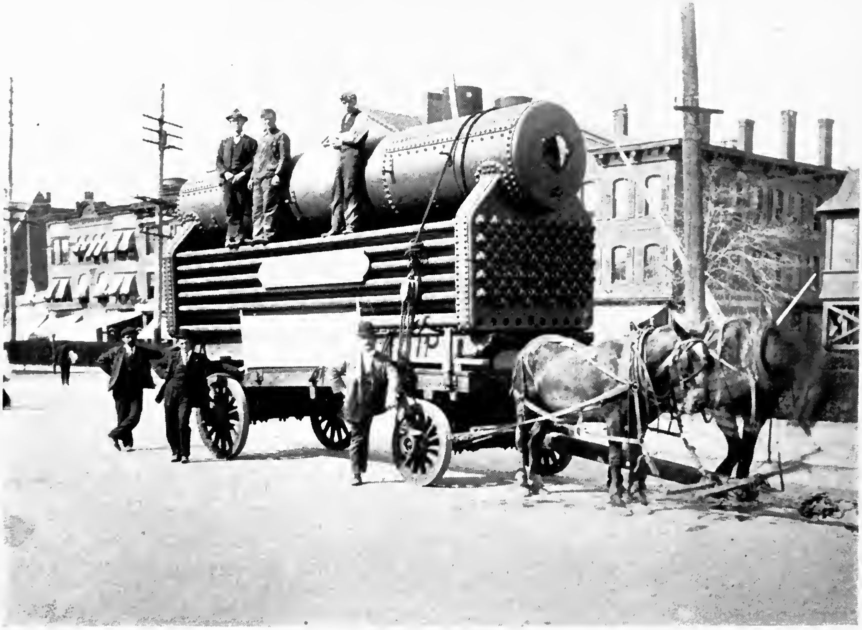
A constant temperature having been obtained, it is evident that the watts lost in each section give an exact measure of the energy lost

in maintaining a constant temperature, and from the watts lost the B. T. U. are readily calculated. Table No. 53 gives results of the tests:

Table No. 53

ELECTRICAL TEST OF STEAM PIPE COVERINGS.

Covering		Average thickness.	B. T. U. loss per sq. ft. at 100 lbs. pres.	% Heat saved by covering.
Solid Cork	Sectional......	1.68	1,672	87.1
85% Magnesia	"	1.18	2,008	84.5
Solid Cork	"	1.20	2,048	84.2
85% Magnesia	"	1.19	2,130	83.6
Laminated Asbestos Cork	"	1.43	2,123	83.7
85% Magnesia	"	1.12	2,190	83.2
Asbestos Air Cell	"	1.26	2,333	82.1
Asbestos Sponge Felted	"	1.24	2,556	80.3
Asbestos Air Cell (Long)	"	1.70	2,750	78.8
"Asbestocel" (Radial)	"	1.22	2,801	78.5
Asbestos Air Cell (Long)	"	1.29	2,812	78.4
"Remanit" (Silk) Wrapped		1.51	1,452	88.8
85% Magnesia	2″ Sectional and ½″ Block	2.71	1,381	89.4
" "	" " ½″ Plaster	2.45	1,387	89.3
" "	2–1″ "	2.50	1,412	89.1
" "	2–1″ "	2.24	1,465	88.7
" "	2″ "	2.24	1,555	88.0
" "	2″ "	2.21	1,568	87.9
Bare Pipe (Outside Tests)			13,000	



EN ROUTE FROM CAR TO FOUNDATION,
FOR FOX HALL PRESSED BRICK CO., PASSAIC, N. J.

BOILER TESTING.

A Committee of the American Society of Mechanical Engineers revised the 1885 code and reported an amended code at the December, 1898, meeting of the Socity, to be known as the Code of 1898. This committee recommended that, as far as possible, the capacity of a boiler be expressed in terms of the number of pounds of water evaporated per hour, from and at 212 degrees Fahrenheit, although they said it was not expedient to abandon the widely recognized measure of capacity expressed in terms of horsepower.

BOILER HORSE POWER VERSUS ENGINE HORSE POWER.

A boiler horse-power, as defined by the Society, is equivalent to 34.5 lbs. of water per hour evaporated from and at 212°F. This is equivalent to 34.5×970.4 B. T. U's. = 33,478.8 B. T. U. This is merely a conventional statement of the capacity as the boiler does no work. The engines run by such a boiler may deliver a horse-power on anywhere from 8.5 lbs. to 50 lbs. of steam per hour. On these bases the boiler horsepower would be equivalent to from 4 engine horsepower to .7 engine horsepower.

It is also practically equivalent to an evaporation of 30 pounds of water from a feed water temperature of 100 degrees Fahrenheit into steam at 70 pounds pressure. The committee also indorsed the statement of the committee of 1885 concerning the commercial rating of boilers, changing it slightly, to read as follows:

"A boiler rated at any stated capacity should develop that capacity when using the best coal ordinarily sold in the market where the boiler is located, when fired by an ordinary fireman, without forcing the fires, while exhibiting good economy; and, further, that the boiler should develop at least one-third more than the stated capacity when using the same fuel and operated by the same fireman, the full draft being employed and the fires being crowded; the available draft at the damper, unless otherwise understood, being not less than ½ inch water column."

RULES FOR CONDUCTING BOILER TESTS.

Code of 1898. (Abridged.)

I. *Determine at the outset* the specific object of the proposed trial, whether it be to ascertain the capacity of the boiler, its efficiency as a steam generator, its efficiency and its defects under usual working con-

ditions, the economy of some particular kind of fuel, or the effect of changes of design, proportion, or operation; and prepare for the trial accordingly.

II. *Examine the boiler*, both outside and inside; ascertain the dimensions of grates, heating surfaces, and all important parts; and make a full record, describing the same, and illustrating special features by sketches. The area of heating surface is to be computed from the outside diameter of water-tubes and the inside diameter of fire tubes.

III. *Notice the general condition* of the boiler and its equipment, and record such facts in relation thereto as bear upon the objects in view.

IV. *Determine the character of the coal* to be used. For tests of the efficiency or capacity of the boiler for comparison with other boilers, the coal should, if possible, be of some kind which is commercially regarded as a standard.

For New England and that portion of the country east of the Allegheny Mountains, good anthracite egg coal, containing not over 10 per cent of ash, and semi-bituminous Clearfield (Pa.), Cumberland (Md.), and Pocahontas (Va.) coals are thus regarded. West of the Allegheny Mountains, Pocahontas (Va.) and New River (W. Va.) semi-bituminous, and Youghiogheny or Pittsburg bituminous coals are recognized as standards.* There is no special grade of coal mined in the Western States which is widely recognized as of superior quality or considered as a standard coal for boiler testing. Big Muddy lump, an Illinois coal mined in Jackson County, Ill., is suggested as being of sufficiently high grade to answer the requirements in districts where it is more conveniently obtainable than the other coals mentioned above.

V. *Establish the correctness of all apparatus* used in the test for weighing and measuring. These are:

1. Scales for weighing coal, ashes, and water.

2. Tanks, or water meters for measuring water. Water meters, as a rule, should only be used as a check on other measurements. For accurate work, the water should be weighed or measured in a tank.

3. Thermometers and pyrometers for taking temperatures of air, steam, feed-water, waste gases, etc.

4. Pressure gauges, draft gauges, etc.

*These coals are selected because they are about the only coals which contain the essentials of excellence of quality, adaptability to various kinds of furnaces, grates, boilers, and methods of firing, and wide distribution and general accessibility in the markets.

The kind and location of the various pieces of testing apparatus must be left to the judgment of the person conducting the test; always keeping in mind the main object, *i. e.*, to obtain authentic data.

VI. *See that the boiler is thoroughly heated* before the trial to its usual working temperature. If the boiler is new and of a form provided with a brick setting, it should be in regular use at least a week before the trial, so as to dry and heat the walls. If it has been laid off and become cold, it should be worked before the trial until the walls are well heated.

VII. *The boiler and connections* should be proved to be free from leaks before beginning a test, and all water connections, including blow and extra feed pipes, should be disconnected, stopped with blank flanges, or bled through special openings beyond the valves, except the particular pipe through which water is to be fed to the boiler during the trial. During the test the blow-off and feed pipes should remain exposed.

If an injector is used, it should receive steam directly through a felted pipe from the boiler being tested.

See that the steam main is so arranged that water of condensation can not run back into the boiler.

VIII. *Starting and Stopping a Test.*—A test should last at least ten hours of continuous running, but, if the rate of combustion exceeds 25 pounds of coal per square foot of grate per hour it may be stopped when a total of 250 pounds of coal has been burned per square foot of grate surface. The conditions of the boiler and furnace in all respects should be, as nearly as possible, the same at the end as at the beginning of the test. The steam pressure should be the same; the water level the same; the fire upon the grates should be the same in quantity and condition; and the walls, flues, etc., should be of the same temperature. Two methods of obtaining the desired equality of conditions of the fire may be used, viz: those which were called in the Code of 1885 "the standard method" and "the alternate method," the latter being employed where it is inconvenient to make use of the standard method.

IX. *Standard Method.*—Steam being raised to the working pressure remove rapidly all the fire from the grate, close the damper, clean the ash pit, and as quickly as possible start a new fire with weighed wood and coal, noting the time and the water level while the water is in a quiescent state, just before lighting the fire.

At the end of the test remove the whole fire, which has been burned low, clean the grates and ash pit and note the water level when the water is in a quiescent state, and record the time of hauling the fire. The water level should be as nearly as possible the same as at the beginning

DENVER GAS AND ELECTRIC LIGHT CO., DENVER COL., CONTAINS 7000 H. P. OF HEINE BOILERS.

of the test. If it is not the same, a correction should be made by computation, and not by operating the pump after the test is completed.

X. *Alternate Method.*—The boiler being thoroughly heated by a preliminary run, the fires are to be burned low and well cleaned. Note the amount of coal left on the grate as nearly as it can be estimated; note the pressure of steam and the water level, and note this time as the time of starting the test. Fresh coal which has been weighed should now be fired. The ash pits should be thoroughly cleaned at once after starting. Before the end of the test the fires should be burned low, just as before the start, and the fires cleaned in such a manner as to leave the bed of coal of the same depth, and in the same condition, on the grates as at the start. The water level and steam pressures should previously be brought as nearly as possible to the same point as at the start, and the time of ending of the test should be noted just before fresh coal is fired. If the water level is not the same as at the start, a correction should be made by computation, and not by operating the pump after the test is completed.

XI. *Uniformity of Conditions.*—In all trials made to ascertain maximum economy or capacity, the conditions should be maintained uniformly constant. Arrangements should be made to dispose of the steam so that the rate of evaporation may be kept the same from beginning to end.

Uniformity of conditions should prevail as to the pressure of steam, the height of water, the rate of evaporation, the thickness of fire, the times of firing and quantity of coal fired at one time, and as to the intervals between the times of cleaning the fires.

XII. *Keeping the Records.*—Take note of every event connected with the progress of the trial, however unimportant it may appear. Record the time of every occurrence and the time of taking every weight and every observation.

The coal should be weighed and delivered to the fireman in equal proportions, each sufficient for not more than one hour's run, and a fresh portion should not be delivered until the previous one has all been fired. The time required to consume each portion should be noted, the time being recorded at the instant of firing the last of each portion. It is desirable that at the same time the amount of water fed into the boiler should be accurately noted and recorded, including the height of the water in the boiler, and the average pressure of steam and temperature of feed during the time. In addition to these records of the coal and the feed water, half hourly observations should be made of the temperature of the feed water, of the flue gases, of the external air in the boiler-room,

of the temperature of the furnace when a furnace pyrometer is used, also of the pressure of steam, and of the reading of the instruments for determining the moisture in the steam. A log should be kept on properly prepared blanks containing columns for record of the various observations.

XIII. *Quality of Steam.*—The percentage of moisture in the steam should be determined by the use of either a throttling or a separating steam calorimeter. The sampling nozzle should be placed in the vertical steam pipe rising from the boiler. It should be made of ½-inch pipe, and should extend across the diameter of the steam pipe to within half an inch of the opposite side, being closed at the end and perforated with not less than twenty ⅛ inch holes equally distributed along and around its cylindrical surface, but none of these holes should be nearer than ½-inch to the inner side of the steam pipe. The calorimeter and the pipe leading to it should be well covered with felting.

Superheating should be determined by means of a thermometer placed in a mercury well inserted in the steam pipe. The degree of superheating should be taken as the difference between the reading of the thermometer for super-heated steam and the readings of the same thermometer for saturated steam at the same pressure as determined by a special experiment, and not by reference to steam tables.

XIV. *Sampling the Coal and Determining its Moisture.*—As each barrow load or fresh portion of coal is taken from the coal pile, a representative shovelful is selected from it and placed in a barrel or box in a cool place and kept until the end of the trial. The samples are then mixed and broken into pieces not exceeding one inch in diameter, and reduced by the process of repeated quartering and crushing until a final sample weighing about five pounds is obtained, and the size of the larger pieces are such that they will pass through a sieve with ¼-inch meshes. From this sample two one-quart, air-tight glass preserving jars or other air-tight vessels which will prevent the escape of moisture from the sample, are to be promptly filled, and these samples are to be kept for subsequent determinations of moisture and of heating value and for chemical analyses. During the process of quartering, when the sample has been reduced to about 100 pounds, a quarter to a half of it may be taken for an approximate determination of moisture. This may be made by placing it in a shallow iron pan, not over three inches deep, carefully weighing it and setting the pan in the hottest place that can be found on the brickwork of the boiler setting or flues, keeping it there for at least 12 hours, and then weighing it. The determination of moisture thus made is believed to be approximately accurate for anthracite and semi-bituminous coals, and also for Pittsburg or Youghiogheny coal; but it can not be relied upon for coals mined west of Pittsburg, or for other

coals containing inherent moisture. For these latter coals it is important that a more accurate method be adopted.

XV. *Treatment of Ashes and Refuse.*—The ashes and refuse are to be weighed in a dry state. For elaborate trials a sample of the same should be procured and analyzed.

XVI. *Calorific Tests and Analysis of Coal.*—The quality of the fuel should be determined either by heat test or by analysis, or by both.

The rational method of determining the total heat of combustion is to burn the sample of coal in an atmosphere of oxygen gas, the coal to be sampled as directed in Article XIV of this Code.

The chemical analysis of the coal should be made only by an expert chemist.

XVII. *Analysis of Flue Gases.*—The analysis of the flue gases is an especially valuable method of determining the relative value of different methods of firing, or of different kinds of furnaces. In making these analyses great care should be taken to procure average samples—since the composition is apt to vary at different points of the flue. The composition is also apt to vary from minute to minute, and for this reason the drawings of gas should last a considerable period of time. Where complete determinations are desired, the analysis should be intrusted to an expert chemist. For approximate determinations the Orsat or the Hempel apparatus may be used by the engineer.

XVIII. *Smoke Observations.*—It is desirable to have a uniform system of determining and recording the quantity of smoke produced where bituminous coal is used. The system commonly employed is to express the degree of smokiness by means of percentages dependent upon the judgment of the observer. The Committee does not place much value upon a percentage method, because it depends so largely upon the personal element, but if this method is used, it is desirable that, so far as possible, a definition be given in explicit terms as to the basis and method employed in arriving at the percentage.

XIX. *Miscellaneous.*—In tests for purposes of scientific research, in which the determination of all the variables entering into the test is desired, certain observations should be made which are in general unnecessary for ordinary tests. These are the measurement of the air supply, the determination of its contained moisture, the determination of the amount of heat lost by radiation, of the amount of infiltration of air through the setting, and (by condensation of all the steam made by the boiler) of the total heat imparted to the water.

As these determinations are not likely to be undertaken except by engineers of high scientific attainments, it is not deemed advisable to give directions for making them.

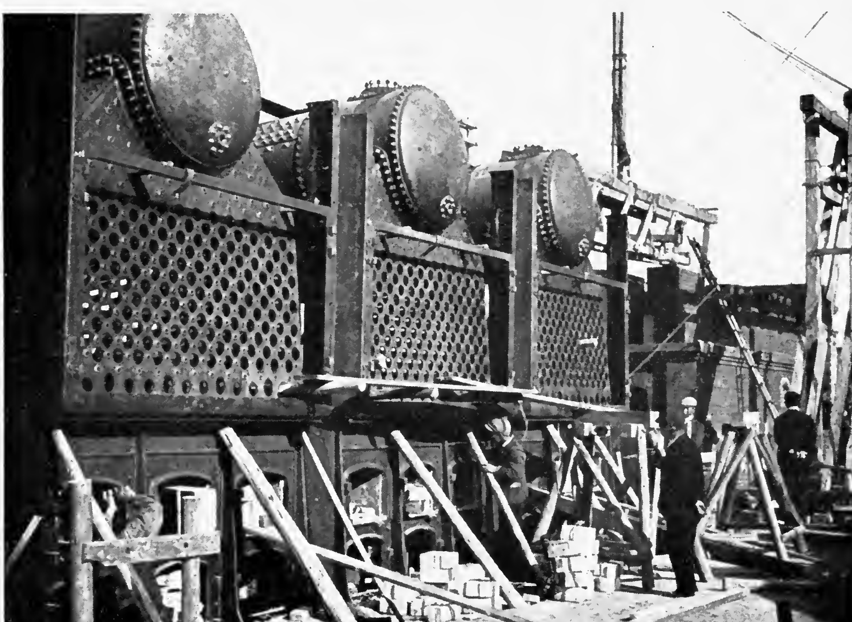
XX. *Calculations of Efficiency.*—Two methods of defining and calculating the efficiency of a boiler are recommended.

1. Efficiency of the boiler $= \dfrac{\text{Heat absorbed per lb. combustible}}{\text{Heating value of 1 lb. combustible}}$

2. Efficiency of the boiler and grate $= \dfrac{\text{Heat absorbed per lb. coal}}{\text{Heating value of 1 lb. coal}}$

The first of these is sometimes called the efficiency based on combustible, and the second the efficiency based on coal. The first is recommended as a standard of comparison for all tests, and this is the one which is understood to be referred to when the word "efficiency" alone is used without qualification. The second, however, should be included in a report of a test, together with the first, whenever the object of the test is to determine the efficiency of the boiler and furnace together with the grate (or mechanical stoker), or to compare different furnaces, grates, fuels, or methods of firing.

The heat absorbed per pound of combustible (or per pound coal) is to be calculated by multiplying the equivalent evaporation from and at 212 degrees per pound combustible (or coal) by 970.4.



THREE 326 H. P. HEINE BOILERS, YOKKAICHI ELEC. LT. CO., YOKKAICHI, JAPAN.

XXI. *The Heat Balance.*—An approximate "heat balance," or statement of the distribution of the heating value of the coal among the several items of heat utilized and heat lost may be included in the report of a test when analyses of the fuel and of the chimney gases have been made. It should be reported in the following form:

HEAT BALANCE, OR DISTRIBUTION OF THE HEATING VALUE OF THE COMBUSTIBLE.

Total heat value of 1 lb. of Combustible.................B. T. U.

	B. T. U.	Per Cent
1. Heat absorbed by the boiler = evaporation from and at 212 degrees per pound of combustible $\times$ 970.4.		
2. Loss due to moisture in coal = per cent. of moisture referred to combustible .. 100 $\times [(212-t) + 970.4 + 0.48\ (T-212)]$ (t = temperature of air in the boiler-room, T = that of the flue gases).		
3. Loss due to moisture formed by the burning of hydrogen = per cent of hydrogen to combustible .. 100 $\times 9 \times [(212-t) + 970\ 4 + 0.48\ (T-212)]$		
4.* Loss due to heat carried away in the dry chimney gases = weight of gas per pound of combustible $\times$ 0.24 $\times$ $(T-t)$.		
5.† Loss due to incomplete combustion of carbon = $\frac{CO}{CO_2 + CO} \times \frac{\text{per cent C in combustible}}{100} \times 10{,}150$.		
6. Loss due to unconsumed hydrogen and hydrocarbons, to heating the moisture in the air, to radiation and unaccounted for. (Some of these losses may be separately itemized if data are obtained from which they may be calculated).		
Totals..		100.00

*The weight of gas per pound of carbon burned may be calculated from the gas analysis as follows:

$$\text{Dry gas per pound carbon} = \frac{11\ CO_2 + 8\ O + 7\ (CO + N)}{3\ (CO_2 + CO)},$$

in which CO_2, CO, O and N are the percentages by volume of the several gases. As the sampling and analyses of the gases in the present state of the art are liable to considerable errors, the result of this calculation is usually only an approximate one. The heat balance itself is also only approximate for this reason, as well as for the fact that it is not possible to determine accurately the percentage of unburned hydrogen or hydrocarbons in the flue gases.

The weight of dry gas per pound of combustible is found by multiplying the dry gas per pound of carbon by the percentage of carbon in the combustible and dividing by 100.

†CO_2 and CO are respectively the percentage by volume of carbonic acid and carbonic oxide in the flue gases. The quantity 10,150 = No. heat units generated by burning to carbonic acid one pound of carbon contained in carbonic oxide.

XXII. *Report of the Trial.*—The data and results should be reported in the manner given in either one of the two following tables, omitting

lines where the tests have not been made as elaborately as provided for in such tables. Additional lines may be added for data relating to the specific object of the test.

The Short Form of Report, Form No. 2, is recommended for commercial tests and as a convenient form of abridging the longer form for publication when saving of space is desirable.

Form No. 2

DATA AND RESULTS OF EVAPORATIVE TEST.

Arranged in accordance with the Short Form advised by the Boiler Test Committee of the American Society of Mechanical Engineers.

Made by................on................boiler, at........................to determine..

Grate surface..	sq. ft.
Water-heating surface..................................	"
Superheating surface...................................	"
Kind of fuel..	
Kind of furnace...	

TOTAL QUANTITIES.

1.	Date of trial..	
2.	Duration of trial...	hours.
3.	Weight of coal as fired..................................	lbs.
4.	Percentage of moisture in coal..........................	per cent.
5.	Total weight of dry coal consumed......................	lbs.
6.	Total ash and refuse......................................	"
7.	Percentage of ash and refuse in dry coal..............	per cent.
8.	Total weight of water fed to the boiler................	lbs.
9.	Water actually evaporated, corrected for moisture or super-heat in steam..	"

HOURLY QUANTITIES.

10.	Dry coal consumed per hour..............................	lbs.
11.	Dry coal per hour per square foot of grate surface...........	"
12.	Water fed per hour..	"
13.	Equivalent water evaporated per hour from and at 212 degrees corrected for quality of steam..........................	"
14.	Equivalent water evaporated per square foot of water-heating surface per hour..	"

AVERAGE PRESSURES, TEMPERATURES, ETC.

15.	Average boiler pressure..................................	lbs. per sq. in.
16.	Average temperature of feed water......................	deg.
17.	Average temperature of escaping gases..................	"
18.	Average force of draft between damper and boiler............	ins. of water
19.	Percentage of moisture in steam, or number of degrees of superheating..	

HORSE-POWER.

20.	Horse-power developed (Item 13 ÷ 34½)..................	H. P.
21.	Builders' rated horse-power.............................	"
22.	Percentage of builders' rated horse-power..................	per cent.

ECONOMIC RESULTS.

23.	Water apparently evaporated per pound of coal under actual conditions. (Item 8 ÷ Item 3)	lbs.
24.	Equivalent water actually evaporated from and at 212 degrees per pound of coal as fired. (Item 13 ÷) (Item 5÷2)	"
25.	Equivalent evaporation from and at 212 degrees per pound of dry coal. (Item 13 ÷ Item 10)	"
26.	Equivalent evaporation from and at 212 degrees per pound of combustible. [Item 13÷ [(Item 5—Item 6) ÷ Item 2]...... (If Items 23, 24 and 25 are not corrected for quality of steam, the fact should be stated.)	"

EFFICIENCY.

27.	Heating value of the coal per pound	B. T. U.
28.	Efficiency of boiler, (based on combustible)	per cent
29.	Efficiency of boiler, including grate (based on coal)	per cent

COST OF EVAPORATION.

30.	Cost of coal per ton delivered in boiler-room	$
31.	Cost of coal required for evaporation of 1,000 pounds of water from and at 212 degrees	$

The observations taken during the test should be recorded on a series of blanks prepared in advance, so as to be adapted for the purpose of the trial. The number of sheets and the number of items on each may be varied to suit the number of observers and the work designated for each. It will be found convenient and desirable to have the blanks for the coal and water observations independent of those for general observations and in general independent of each other. In all cases the first column of the coal record and of the water record should be devoted to the time; stating, for instance, when a particular barrow of coal is dumped or a particular tank of water let down. Error is best avoided by having separate columns for gross weights, tare and net weights, even though the tare be constant. The ed-water record should contain a column for temperature in case the same is taken in the tank, and also a column for height of water in glass gauge on boiler, which is to be noted when tank is emptied if the feed pump or injector is directly connected thereto.

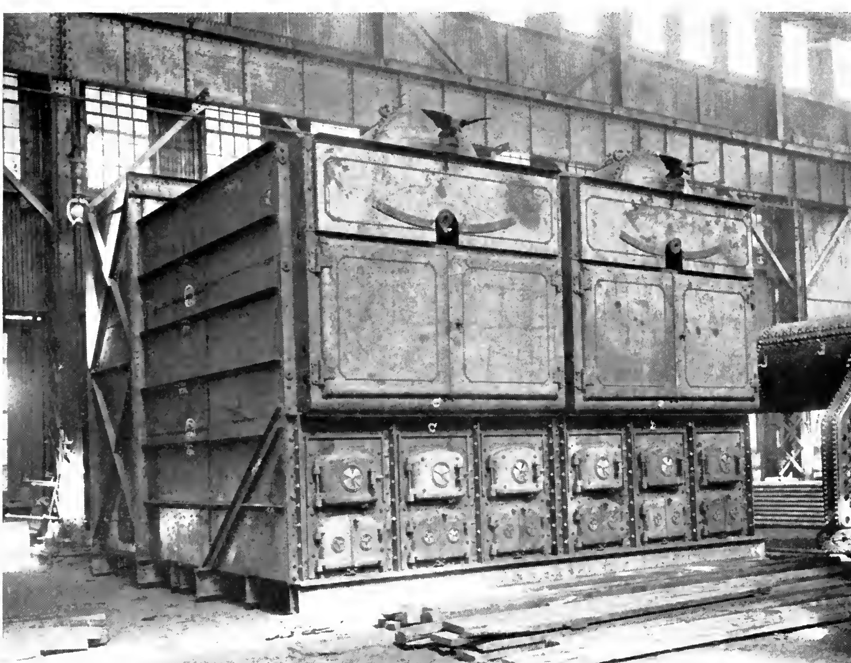
It is agreed that the coal should be weighed and the water measured or weighed at practically regular intervals, and that in every case the *time* be put down when a bucket of coal is dumped or a tank of water let down, when, by simple reference to the clock, all disputes as to neglected tallies will be eliminated.

To the report are appended a number of suggestions as to the modus operandi of making certain ones of the various determinations, but while of great value, these cannot be printed in this volume, because of lack of space.

THE ENERGY STORED IN STEAM BOILERS.

R. H. T.

A steam boiler is not only an apparatus by means of which the potential energy of chemical affinity is rendered actual and available, but it is also a storage reservoir, or a magazine, in which a quantity of such energy is temporarily held; and this quantity, always enormous, is directly proportional to the weight of water and of steam which the boiler at the time contains. The energy of gunpowder is somewhat variable, but a cubic foot of heated water under a pressure of 60 or 70 lbs. per square inch has about the same energy as one pound of gunpowder. At a low red heat water has about 40 times this amount of energy. Following are presented the weights of steam and of water contained in each of the more common forms of steam boilers, the total and relative amounts of energy confined in each under the usual conditions of working in every day practice, and their relative destructive power in case of explosion.



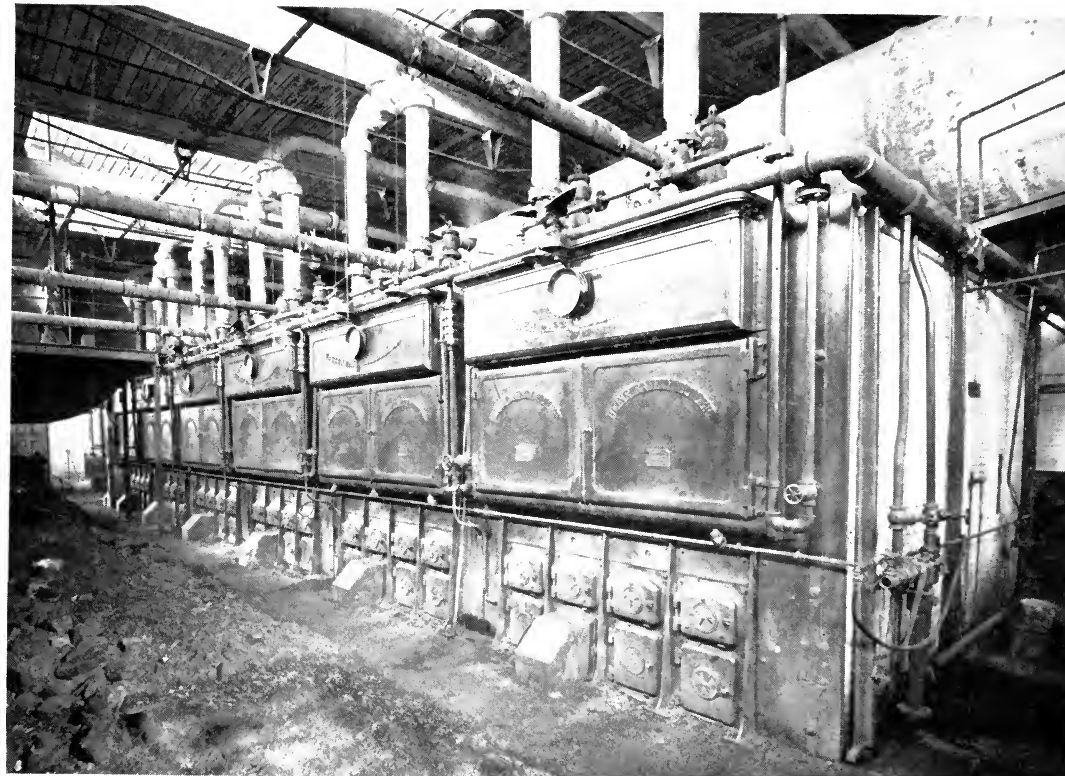
TWO 300 H. P. HEINE BOILERS WITH MARINE SETTING, FOR DREDGE BOAT ON N. Y. BARGE CANAL.

Table No. 54

TOTAL STORED ENERGY OF STEAM BOILERS.

TYPE	AREA OF		Pressure, Pounds per Square Inch.	Rated Power, H P.	WEIGHT OF			AVAILABLE STORED ENERGY IN			ENERGY PER LB. OF		MAXIMUM HEIGHT OF PROJECTION*		INITIAL VELOCITY	
	Grate Surf.	Heat Surf.			Boiler	Water	Steam	Water	Steam	Total	Boiler	Total Wt.	Boiler	Total	Boiler	Total
	Square Feet				Pounds			Foot Pounds			Foot Lbs.		Feet		Ft. per Sec.	
1. Plain Cylinder	15	120	100	10	2500	5764	11.325	46605200	676698	47281898	18913	5714	18913	5714	1103	606
2. Cornish	36	730	30	60	16950	27471	31.45	57570750	709310	58260060	3431	1314	3431	1314	471	290
3. Two-flue Cylinder	20	400	150	35	6775	6840	37.04	80572050	2377357	82949407	12243	6076	12243	6076	888	625
4. Plain Tubular	30	852	75	60	9500	8255	20.84	50008790	1022731	51031521	5372	2871	5372	2871	588	430
5. Locomotive	22	1070	125	525	19400	5260	21.67	52561075	1483896	54044971	2786	2189	2786	2189	423	375
6. Locomotive	30	1350	125	650	25000	6920	31.19	69148790	2135802	71284592	2851	2231	2851	2231	428	379
7. Locomotive	20	1200	125	600	20565	6450	25.65	64452270	1766447	66218717	3219	2448	3219	2448	455	397
8. Locomotive	15	875	125	425	14020	6330	19.02	64253160	1302431	65555591	4677	3213	4677	3213	549	455
9. Scotch Marine	32	768	75	300	27045	11765	29.80	71272370	1462430	72734800	2689	1873	2689	1873	416	348
10. Scotch Marine	50.5	1119.5	75	350	37972	17730	47.20	107408340	2316392	109724732	2889	1968	2889	1968	431	356
11. Flue and Return Tubular	72.5	2324	30	200	56000	42845	69.81	90531490	1570517	92101987	1644	931	1644	931	325	245
12. Flue and Return Tubular	72	1755	30	180	56000	48570	73.07	102628410	1643854	104272264	1862	996	1862	996	346	253
13. Water Tube	70	2806	100	250	34450	21325	35.31	172455270	2108110	174563380	5067	3073	5067	3073	571	445
14. Water Tube	100	3000	100	250	45000	28115	58.50	227366000	3513830	230879830	5130	3155	5130	3155	575	450
15. Water Tube	100	3000	100	250	54000	13410	23.64	108346670	1311377	199624283	2030	1626	2030	1626	361	323

*This means the height to which the total weight could be projected by the available energy.



SEVEN OF TEN 320 H. P. HEINE BOILERS, WARREN MFG. CO., WARREN, R. I.

THE BOILER.

THE modern boiler is one which successfully fulfills several conditions, which are demanded by the best practice. Briefly, these conditions are economy of fuel, safety and durability of the boiler, economy of space occupied, accessibility for both internal and external cleaning. The successful fulfillment of each of these points is dependent on the compliance with certain fundamental principles, which are given below in a concise form.

ECONOMY OF FUEL.

That boiler, which will deliver the greatest quantity of dry steam for each pound of fuel burned in the furnace, other conditions being equal, is obviously the most economical in the use of fuel.

To secure this result three conditions must be met:—

FIRST: Complete combustion of the fuel must be secured; in other words, the furnace must be properly designed. Sufficient time must be allowed for the gases from the fuel to be properly burned before coming in contact with the heating surface, which, considered in relation to the hot gases, is the cooling surface, of the boiler. The furnaces of the great majority of boilers are still fired by hand, a flat stationary or shaking grate being used. A fairly deep fire box, as measured from the boiler to the grate surface, should be provided, in which, above the fuel, the combustible gases can continue burning. It is of the greatest importance that there should also be provided a spacious combustion chamber, in which the burning of the mixture of air and gases can be completed, thus giving the time element required before the cooling process commences. To cool these gases before this combustion is complete means a serious loss in economy due to the escaping of unburned hydrocarbons. If this process of combustion takes place under a fire brick roof as well as between fire brick walls it is greatly benefited.

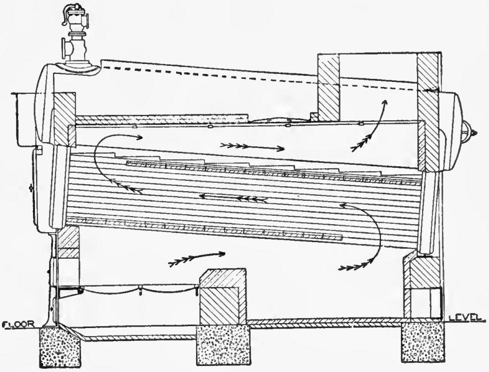


Fig. 1.

SECOND: The hot gases must be properly brought in contact with the heating surfaces. There are two methods of doing this, (a) by causing the gases to travel parallel to the heating surface, (Fig. 1), (b) by causing them to

travel at approximately right angles to the surface (Fig. 2). The first is the one in universal use in connection with the oldest and still most widely used type of boiler, the horizontal return tubular. Long experience, as well as numerous experiments, show this to be the correct practice and that a larger amount of heat is absorbed per unit of surface exposed than where the gases are applied as in the second method. (See Engineering Record of February, 1898, p. 258).

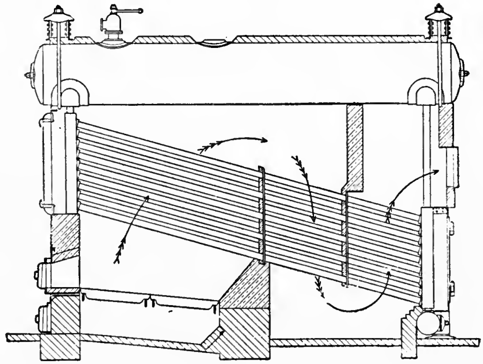


Fig. 2.

THIRD: The water in the boiler must have a rapid and positive circulation in order to take up the heat as rapidly as possible, the steam thus generated being replaced at once by more water, thus preventing the overheating of the metal as well as reducing the temperature of the gases to as low a point as possible before they pass away from the boiler. Another factor affecting the economy of fuel is the necessity of causing the steam to pass into the piping without any entrained moisture, since any such moisture carries with it a considerable amount of heat, which not only can do no useful work but is likely to do positive injury of a mechanical nature.

SAFETY AND DURABILITY OF THE BOILER.

The proper design of the structure of a boiler is a complicated and delicate matter. There are so many places where it is absolutely impossible to calculate the stresses that the element of judgment is of great importance. There are many generally recognized rules for determining the strength of the principal parts and the tendency is to lay down regulations covering every possible condition, which regulations should be based on a combination of theory, practice and judgment. The boiler rules recently issued by the State of Massachusetts are by far the best that have as yet appeared.

The four main points to be observed in making a boiler safe and durable are:

FIRST: All parts which are subjected to any stresses whatever, whether due to internal pressure of the steam or to the weight of the boiler itself, should be made of material of the very best quality and preferably of such a nature that the quality can be determined with absolute

certainty. Consequently the best open hearth steel or forged metal of undoubted quality should be used for all such parts. The use of cast iron in the construction of a boiler for any parts subjected to any of the stresses above mentioned should be studiously avoided. Its use in parts subject to tensile stresses has been prohibited by the American Boiler Manufacturer's Association since 1889.

SECOND: The parts should be designed and proportioned with regard to the stresses which they will be called upon to sustain. For economical reasons each part should be made as strong as every other part, giving due consideration, however, to the placing of excess strength where any deterioration is likely to take place.

THIRD: The workmanship should be of the best. As a rule the more machine work that can be done the better, on the principle that a machine designed to do a certain work properly can be depended on to do that work in a far more uniform manner than when done by hand.

FOURTH: Ample provision should be made to permit the unavoidable movements due to expansion and contraction to take place without straining the boiler or disturbing the brick setting.

The American Boiler Manufacturers' Association at their Convention in St. Louis in 1898 adopted specifications covering the details of manufacture of boilers and have from time to time since modified these, which we here publish in an abbreviated form as issued by the Committee under authority of the Association.

UNIFORM AMERICAN BOILER SPECIFICATIONS
ADOPTED BY THE
AMERICAN BOILER MANUFACTURERS' ASSOCIATION.

(See Proceedings 1889, pp. 49, 50, 66-81, 84-88.
(See Proceedings 1897, pp. 42-54, 61-77, 207-208.)
(See Proceedings 1898, pp. 49-100.)
(See Proceedings 1905. p. 164.)
(See Proceedings 1909, pp. 108-111.)
(See Proceedings 1910, pp. 77, 78.)

(At the Tenth Annual Convention of the American Boiler Manufacturers' Association, held at St. Louis, Mo., October 3-6, 1898, were unanimously adopted a complete set of boiler specifications, known as the Uniform American Boiler Specifications. These contain in addition to the requirements as to materials, methods and calculations, many reasons, arguments and explanations. The chairman of the committee was instructed to prepare an abridged form containing only the mandatory clauses, This after submission to the other members of the committee and approval by them is here published.)

I. MATERIALS.

1. Cast Iron—Should be of soft, gray texture and high degree of ductility. To be used only for hand-hole plates, crabs, yokes, etc., and manheads. It is a dangerous metal to be used in mud drums, legs, necks, headers, manhole rings or any part of a boiler subject to tensile strains; its use is prohibited for such parts.

2. Steel—Homogeneous steel made by the open hearth or crucible processes, and having the following qualities, is to be used in all boilers.

	T. S.
Flange or Boiler Steel	55000 to 65000 lbs.

When it is stipulated that the plates are to be flanged, the physical properties shall be the same as required for Fire Box Steel.

	T. S.
Fire Box Steel	52000 to 62000 lbs.
Extra Soft Steel	45000 to 55000 lbs.

	Elongation in 8 inches.
Flange or Boiler Steel	25%
Fire Box Steel	26%
Extra Soft Steel	28%

	Chemical Requirements. Sul.	Phos.
Flange or Boiler Steel Fire Box Steel Extra Soft Steel	.03%	.04%

For all plates the elastic limit to be at least one-half the ultimate strength; percentage of manganese and carbon left to the judgment of the steel maker.

Test Section to be 8 inches long, planed or milled edges; its cross sectional area not less than one-half of one square inch, nor width less than the thickness of the plate.

Steel up to ½ inch thickness must stand bending double and being hammered down on itself; above that thickness it must bend round a mandrel of diameter of one and one-half times the thickness of plate down to 180 degrees. All without showing signs of distress.

Bending test piece to be in length not less than sixteen times thickness of plate, and rough, shear edges milled or filed off. Such pieces to be cut both lengthwise and crosswise of the plate.

All tests to be made at the steel mill. Three pulling tests and three bending tests to be made from each heat. If one fails the manufacturer may furnish and test a fourth piece, but if two fail the entire heat to be rejected.

Certified copies of tests to be furnished each member of A. B. M. A. from heats from which his plates are made.

3. RIVETS to be good charcoal iron, or of soft, mild steel having the same physical and chemical properties as the fire box plates, and must test hot and cold by driving down on an anvil with the head in a die; by nicking and bending, by bending back on themselves cold, without developing cracks or flaws.

4. BOILER TUBES, of charcoal iron or mild steel specially made for the purpose, and lap welded or drawn; they should be round, straight, free from scales, blisters and mechanical defects, each tested to 500 pounds internal hydrostatic pressure.

This fact and manufacturer's name to be plainly stenciled on each tube.

STANDARD THICKNESSES by Birmingham wire gauge to be:—

No. 13 for tubes 1 in., 1¼ in., 1½ in. and 1¾ in. diameter.
No. 12 for tubes 2 in., 2¼ in. and 2½ in. diameter.
No. 11 for tubes 2¾ in., 3 in., 3¼ in. and 3½ in. diameter.
No. 10 for tubes 3¾ in., and 4 in. diameter.
No. 9 for tubes 4½ in., and 5 in. diameter.

A test section cut from one tube taken at random from a lot of 150 or less must stand hammering down cold vertically without cracking or splitting when down solid.

Length of test pieces to be:—

¾ inch for tubes from 1 in. to 1¾ in. diameter.
1 inch for tubes from 2 in. to 2½ in. diameter.
1¼ inch for tubes from 2¾ in. to 3¼ in. diameter.
1½ inch for tubes from 3½ in. to 4 in. diameter.
1¾ inch for tubes from 4½ in. to 5 in. diameter.

All tubes must stand expanding flange over on tube plate and bending without flaw, crack or opening of the weld.

5. STAY BOLTS to be made of iron or mild steel specially manufactured for the purpose, and must show on:

Test Section 8 inches long, net:

FOR IRON, tensile strength not less than 46,000 lbs.; elastic limit not less than 26,000 lbs.; elongation not less than 22 per cent for bolts of less

HOTEL RECTOR, NEW YORK, N. Y.
CONTAINS 720 H. P. OF HEINE BOILERS.

than one (1) square inch area, nor less than 20 per cent for bolts one (1) square inch and more in net area.

For Steel, tensile strength not less than 55,000 lbs.; elastic limit not less than 33,000 lbs.; elongation not less than 25 per cent for bolts of less than one (1) square inch area, nor less than 22 per cent for bolts one (1) square inch and more in net area.

A bar taken from a lot of 1,000 lbs. or less at random, threaded with a sharp die "V" thread with rounded edges, must bend cold 180 deg. around a bar of same diameter without showing any crack or flaws.

Another piece, similarly chosen, and threaded, to be screwed into well fitting nuts formed of pieces of the plates to be stayed, and riveted over so as to form an exact counterpart of the bolt in the finished structure; to be pulled in testing machine and breaking stress noted; if it fails by pulling apart the tensile stress per square inch of net section is its measure of strength; if it fails by shearing the shear stress per square inch of mean section in shear is this measure. The mean section in shear is the product of half the thickness of the plate by the circumference at half height of thread.

6. Braces and Stays. Material to be fully equal to stay bolt stock, and tensile strength to be determined by testing a bar not less than ten inches (10 in.) long from each lot of 1000 lbs. or less.

II. WORKMANSHIP AND DIMENSIONS.

7. Flanging, Bending and Forming to be done at a heat suited to the material, but no bending must be done or blow struck on any plate which no longer shows red by daylight at the working point and at least 4 inches beyond it.

8. Rolling must be done cold by gradual and regular increments from the straight plate to the exact circle required and the whole circumference including the lap rolled to a true circle.

9. Bumped Heads uniformally dished to a segment of a sphere should have a thickness equal to that of a cylindrical shell of solid plate of same material, whose diameter is equal to the radius of curvature of the dished head. Rivet holes, man holes, etc., to be allowed for by proportionate increase in the thickness.

10. Riveting. Holes made perfectly true and fair by clean cutting punches or drills. Sharp edges and burrs removed by slight counter sinking and burr reaming before and after sheets are joined together.

Under side of original rivet head must be flat, square and smooth. For rivets $\frac{5}{8}$ inch to $\frac{13}{16}$ inch diameter allow $1\frac{1}{2}$ diameters for length of stock to form the head, and less for larger rivets. Allow 5 per cent more stock for driven head for button set or snap rivets. Use light regulation riveting hammers until rivet is well upset in the hole; after that snap and heavy mauls. For machine riveting more stock is to be left for driven head to make it equal to orignal head, as fixed by experiment.

Total pressure on the die about 80 tons for $1\frac{1}{8}$ inch to $1\frac{1}{4}$ inch rivets; 65 tons for 1 inch; 57 tons for $\frac{15}{16}$ inch; 35 tons for $\frac{3}{4}$ inch rivets.

Make heads of rivets equal in strength to shanks by making head at periphery of shank of a height equal to $\frac{1}{3}$ diameter of shank and giving a slight fillet at this point.

Approximately make rivet holes double thickness of thinnest plate; pitch three times rivet hole; pitch lines of staggered rows $\frac{1}{2}$ pitch apart; lap for single riveting equal to pitch, for double riveting $1\frac{1}{3}$ pitch, and $\frac{1}{2}$ pitch more for each additional row of rivets; exact dimensions determined by making resistance to shear of aggregate rivet section at least 10 per cent greater than tensile strength of net or standing metal.

11. Rivet Holes punched with good sharp punches and well fitting dies in A. B. M. A. steel up to $\frac{5}{8}$ inch thickness; in thicker plates punch and ream with a fluted reamer or drill the holes.

12. Drift Pin to be used only with light hammers to pull plates into place and round up the hole, but never to enlarge or gouge holes with heavy hammers.

13. Calking to be done by hand or pneumatic hammer and Conery or round nosed tool. Avoid excessive calking; the fit must be made in the laying of the plates. The square nosed tool may be used for finishing with great care to avoid nicking lower plate. Calking edges must be prepared by bevel planing, shearing or chipping.

14. Flat Surfaces. State the thickness of the plate "t" in sixteenths of an inch, the pitch "p" in inches, and use a constant:

C=112 for plates $\frac{7}{16}$ inch and under with screw stays with riveted ends.

C=120 for plates over $\frac{7}{16}$ inch with screw stays with riveted ends.

C=140 for all plates when in addition to screw threads in the plates a nut is used inside and outside of each plate.

When salt, acids or alkali are contained in the feed water, this latter construction is imperative.

Rule—Multiply this constant "C" by the square of the thickness of the plate expressed in sixteenths of an inch, and divide by the square

of the pitch expressed in inches; the quotient is the safe working pressure "P."

$$\text{Formula:}\quad P = \frac{C \times t^2}{p^2}$$

15. Tube Holes either punched $\frac{1}{8}$ inch less than required diameter and reamed to full size, or drilled; then slightly countersunk on both sides; should be $\frac{1}{64}$ inch to $\frac{1}{16}$ inch larger than diameter of tube according to size of tube; if copper ferrules are used the hole to be a neat fit for the ferrule. Tube sheet to be annealed after punching and before reaming.

16. Tube Setting. Ends of tubes to be annealed (at the Tube Mill) before setting. The tube to extend through the sheet $\frac{1}{16}$ inch for every inch of diameter. Expand until tight in hole and no more. On end exposed to direct flame, flange the tube partly over on sheet, finishing by beading tool which must not come in contact with the plate; expand slightly after beading.

Copper ferrules No. 18 to 14 wire guage should be used in fire tube boiler on ends subject to direct heat.

17. Riveted and Lap Welded Flues, as prescribed in Rule 11, Sections 8, 9, 10, 11, 12 and 13 of Regulations of Board of Supervising Inspectors of Steam Vessels, approved February, 1895.

18. Corrugated Furnace Flues as prescribed in sections 14 and 15 of the same Rule.

19. Stay Bolts to be carefully threaded with sharp clean dies "V" thread with round edges; threading machine equipped with a lead screw; holes tapped with tap extending through both sheets to neat smooth fit, so that bolts can be put in by hand lever or wrench with a steady pull; $\frac{1}{5}$ diameter to project for riveting over; with hollow staybolts use slender drift pin in the bore while riveting and drive it home to expand the bolt after riveting.

Height of nuts used on screw stays to be at least 50 per cent of diameter of stay. Largest permissible pitch for screw stays is 10 inches.

20. Braces and Stays shall be subjected to careful inspection and tests as per section 6 and 2. Welding to be avoided where possible, but good clean welds to be allowed a value of 80 per cent of the solid bar. Rivets by which braces are attached, when the pull on them is other than at right angles to be allowed only half the stress permitted for rivets in the seams.

21. Manholes should be flanged in, out of the solid plate, on a radius not less than three times the metal thickness to a straight flange; when the plate is $\frac{1}{2}$ inch or less in thickness a reinforce ring to be shrunk around it. Cast iron reinforce flanges never to be used.

U. S. CUSTOM HOUSE, NEW YORK, N. Y., CONTAINS 1200 H. P. OF HEINE BOILERS.

22. Domes to be avoided when possible; cylindrical portion to be flanged down to the shell of the boiler, and this shell flanged up inside the dome, or reinforced by a collar flanged at the joint, the flanges double riveted.

23. Drums should be put on with collar flanges of A. B. M. A. steel, not less than ⅜ inch thick double riveted to shell and drum and single riveted to the neck or leg, or the flanges may be formed on these legs.

24. Saddles or Nozzles to be of flanged steel plate or of soft cast steel, never of cast iron.

III. FACTORS OF SAFETY.

25. Rivet Seams when proportioned as prescribed in Section 10 with materials tested as per Sections 2 and 3 shall have 4½ as factor of safety; when not so tested, but inspection of materials indicates good quality, a factor of safety of 5 is to be taken, and at most 55,000 lbs. tensile strength assumed for the steel plate and 40,000 lbs. shear strength for the rivets, all figured on the actual net standing metal.

26. Flat Surfaces proportioned as per Section 14 have in the constants there given a factor of safety of 5 or a little over.

27. Bumped Heads proportioned as per Section 9 to be subject to a factor of safety of 5.

28. Stay Bolts proportioned and tested as per sections 19 and 5 to have a factor of safety of 5 applied to the lowest stress found.

29. Braces and Stays. When tested as per Section 6 and 2 to be allowed a factor of safety of 5; when not so tested but careful inspection shows good stock they may be used up to 6,500 lbs. actual direct pull for wrought iron, and 8,000 lbs. for mild steel, all per square inch of actual net metal.

IV. HYDROSTATIC PRESSURE.

30. The Hydrostatic Test, to be made on completed boilers built strictly to these specifications, is never to exceed working pressure by more than one-third of itself and this excess limited to 100 lbs. per square inch. The water used for testing to have a temperature of at least 125 deg. F.

V. HANGING OR SUPPORTING THE BOILER.

31. The boiler should be supported on points where there is the greatest excess of strength. Excessive local stresses from weight of boiler

and contents must be avoided and distortion of parts prevented by using long lugs or brackets, and only half the stress which they may carry in the seams, to be allowed on rivets.

The supports must permit rebuilding the furnace without disturbing the proper suspension of the boiler. The boiler should be slightly inclined so that a little less water shows at the guage cocks than at the opposite end.

E. D. Meier, Chairman.
Henry J. Hartley.
John Mohr.
James G. Mitchell.
James C. Stewart.
James Lappan.
George N. Riley
D. Connelly.

ECONOMY IN SPACE OCCUPIED.

The space occupied by a boiler of any given capacity, both as regards floor area and height, depends mainly on the compact arrangement of the heating surface, although the limiting factor as regards the floor area is the extent of grate surface on which the fuel must be burned. There are certain ratios of grate area to heating surface that cannot be ignored, these ratios being dependent upon the nature and intensity of the draft, kind of fuel, grates, etc., and may range between 1 to 40 and as high as 1 to 80 or even 100. Coupled with this is the consideration of that design which best provides cleaning facilities, and that boiler, which admits of the best combination of the various points in any given case, is most ecomical of floor space.

ACCESSIBILITY FOR CLEANING.

Both internally and externally a boiler of any type will accumulate, to a greater or less extent, foreign matter, which is detrimental to its operation, and in many cases to its durability as well. On the interior surfaces there will be deposited from almost all kinds of water, solids which are normally in solution. A small amount of this accumulation, or scale as it is usually called, ordinarily does no particular harm but any great accumulation will prevent, to some extent, transfer of heat, which not only means a loss in economy but is likely to cause overheating of the metal with resulting damage to the boiler. If at least a portion of these

solids can be precipitated before entering the boiler it should by all means be done, but since it is rarely the case that even a small part of the impurities are so extracted, it is highly desirable that means be provided for precipitating them inside the boiler in a special receptacle, so they can be blown out. It is not practicable, however, to precipitate all the solids, and hence it should be possible to get at all deposits of this nature on the interior of the boiler in order to positively, conveniently and quickly remove them.

On the exterior surfaces of the boiler there will accumulate a certain amount of dust and soot, which is very detrimental to the economy of fuel and positive means should be provided for removing these accumulations. Preferably it should be possible to do this without interfering with the operation of the boiler, and any such means provided should avoid the necessity of admitting cold air in quantities. The admission of such cold air has a tendency to set up injurious strains in the structure due to the contractive and expansive movements, as well as to lower the economy due to the cooling of the hot gases. In short every part of the boiler should be open to inspection and so accessible that every part may be conveniently reached with the appropriate cleaning tool.

SAFETY VALVES.

The United States Department of Commerce and Labor, through its Board of Supervising Inspectors, Steamboat-Inspection Service, has established rules relating to safety valves and from which the following are extracts:

"The area of all safety valves on boilers contracted for or the construction of which commenced on or after June 1, 1904, shall be determined in accordance with the following formula:

$$\text{Formula: } a = 0.2074 \times \frac{W}{P}$$

Where a = area of safety valve, in square inches, per square foot of grate surface.

W = pounds of water evaporated per square foot of grate surface per hour.

P = absolute pressure pounds per square inch = working gauge pressure + 15.

"From which formula the areas required per square foot of grate surface in the accompanying (Table No. 55) are found by assuming the different values of W and P.

"The figures (a) in this table multiplied by square feet of grate surface give area of safety valve or valves required.

Table No. 55.

TABLE OF AREA OF SAFETY VALVES REQUIRED PER SQUARE FOOT OF GRATE SURFACE FOR DIFFERENT PRESSURES AND RATES OF EVAPORATION.

Absolute Pressure Per Square Inch.	Gauge Pressure Per Square Inch.	These figures represesent evaporation in pounds per square foot of grate surface per hour = pounds water evaporated per pound coal × pounds coal burned per square foot of grate surface per hour.														
		100	120	140	160	180	200	220	240	260	280	300	320	340	360	380
		The figures below give the area in square inches required per square foot of grate surface at the above rate of evaporation.														
65	50	.319	.383	.447	.510	.547	.638	.702	.765	.829	.893	.956				
70	55	.296	.355	.414	.474	.533	.592	.652	.711	.769	.828	.888				
75	60	.276	.332	.387	.442	.497	.552	.608	.663	.718	.773	.829				
80	65	.259	.311	.363	.415	.466	.518	.570	.622	.674	.726	.778				
85	70	.244	.292	.341	.390	.438	.487	.536	.585	.634	.682	.731				
90	75	.230	.276	.322	.368	.414	.460	.506	.552	.598	.644	.690				
95	80	.218	.262	.305	.349	.392	.436	.479	.523	.567	.610	.654				
100	85	.207	.249	.290	.332	.373	.414	.456	.497	.538	.580	.622				
105	90	.197	.236	.276	.316	.355	.394	.434	.473	.513	.552	.592				
110	95	.188	.226	.264	.301	.339	.377	.414	.452	.489	.527	.565				
115	100	.180	.216	.252	.288	.324	.360	.396	.432	.468	.504	.540				
120	105	.172	.207	.241	.276	.311	.345	.379	.414	.448	.483	.517				
125	110	.166	.199	.232	.265	.298	.331	.364	.397	.431	.463	.497				
130	115	.160	.192	.223	.255	.287	.319	.351	.383	.415	.447	.479				
135	120	.153	.184	.215	.246	.276	.307	.337	.368	.398	.429	.460				
140	125	.148	.177	.207	.237	.266	.296	.325	.355	.385	.414	.444				
145	130	.143	.172	.201	.229	.258	.287	.315	.344	.372	.401	.430				
150	135	.138	.166	.194	.222	.249	.277	.304	.332	.360	.387	.415				
155	140	.134	.160	.187	.214	.241	.268	.294	.321	.348	.375	.401				
160	145	.130	.156	.181	.207	.233	.259	.285	.311	.337	.363	.389				
165	150	.126	.151	.176	.201	.226	.251	.276	.301	.326	.352	.378				
170	155	.122	.146	.171	.195	.219	.244	.268	.292	.317	.341	.366				
175	160	.118	.142	.166	.189	.213	.236	.260	.284	.308	.331	.355				
180	165	.115	.138	.161	.184	.207	.230	.254	.277	.300	.323	.346				
185	170	.112	.135	.157	.179	.202	.224	.247	.269	.291	.314	.336				
190	175	.100	.131	.153	.175	.196	.218	.240	.262	.284	.306	.328				

Table No. 55—Continued.

TABLE OF AREA OF SAFETY VALVES REQUIRED PER SQUARE FOOT OF GRATE SURFACE FOR DIFFERENT PRESSURES AND RATES OF EVAPORATION.

Absolute Pressure Per Square Inch.	Gauge Pressure Per Square Inch.	These figures represent evaporation in pounds per square foot of grate surface per hour = pounds water evaporated per pound coal × pounds coal burned per square foot of grate surface per hour.														
		100	120	140	160	180	200	220	240	260	280	300	320	340	360	380
		The figures below give the area in square inches required per square foot of grate surface at the above rate of evaporation.														
195	180	.106	.128	.149	.170	.191	.213	.234	.255	.277	.298	.319				
200	185	.104	.124	.145	.166	.187	.207	.228	.249	.270	.290	.310				
205	190	.101	.121	.142	.162	.182	.202	.223	.243	.263	.283	.303				
210	195	.099	.119	.138	.158	.176	.198	.217	.237	.257	.277	.297				
215	200	.096	.116	.135	.154	.173	.193	.212	.231	.250	.269	.289	.308	.327	.347	.366
220	205	.094	.113	.132	.151	.170	.189	.208	.226	.245	.264	.283	.302	.321	.340	.358
225	210	.092	.110	.129	.147	.166	.184	.203	.221	.240	.258	.276	.295	.314	.332	.350
230	215	.090	.108	.126	.144	.162	.180	.198	.216	.235	.253	.270	.289	.307	.325	.343
235	220	.088	.106	.124	.141	.159	.176	.194	.212	.229	.247	.264	.282	.300	.318	.336
240	225	.086	.104	.121	.138	.155	.173	.190	.207	.225	.242	.259	.276	.294	.311	.329
245	230	.085	.102	.119	.135	.152	.170	.186	.203	.220	.237	.254	.271	.288	.305	.322
250	235	.083	.100	.117	.133	.149	.167	.183	.199	.216	.233	.249	.266	.282	.299	.315
255	240	.081	.098	.114	.130	.146	.163	.179	.195	.211	.228	.244	.261	.277	.293	.309
260	245	.080	.096	.112	.128	.144	.160	.176	.192	.208	.224	.240	.255	.271	.287	.303
265	250	.078	.094	.110	.125	.141	.157	.172	.188	.203	.219	.235	.250	.266	.282	.298
270	255	.077	.092	.107	.123	.138	.153	.169	.184	.199	.215	.230	.245	.261	.276	.291
275	260	.075	.090	.105	.121	.136	.151	.166	.181	.196	.211	.226	.241	.256	.271	.286
280	265	.074	.089	.104	.118	.133	.148	.163	.178	.192	.207	.222	.237	.251	.266	.281
285	270	.073	.087	.102	.116	.131	.146	.160	.175	.189	.204	.218	.233	.247	.262	.276
290	275	.072	.086	.100	.114	.129	.143	.157	.172	.186	.200	.214	.228	.242	.257	.271
295	280	.070	.084	.098	.112	.127	.141	.154	.169	.182	.196	.210	.225	.238	.253	.267
300	285	.069	.083	.096	.110	.124	.138	.151	.166	.179	.193	.207	.221	.235	.249	.263
305	290	.068	.082	.095	.109	.122	.136	.149	.163	.177	.190	.204	.217	.231	.245	.258
310	295	.067	.080	.093	.107	.120	.134	.147	.160	.174	.187	.201	.214	.227	.241	.254
315	300	.066	.079	.092	.105	.118	.132	.145	.158	.171	.184	.197	.210	.223	.237	.250

HANDLING 260 H. P. HEINE BOILER ONTO STEAMBOAT CHESTER
NEW ORLEANS, LA.

"When this calculation results in an odd size of safety valve, use next larger standard size.

"To determine the area of a safety valve for a boiler using oil as fuel or for boilers designed for any evaporation per hour:

"Divide the total number of pounds evaporated per hour by any number of pounds of water evaporated per square foot of grate surface per hour (W) taken from, and within the limits of the table. This will give the equivalent number of square feet of grate surface for boiler for estimating the area of valve.

"The valves shall be so arranged that each boiler shall have at least one separate safety valve, unless the arrangement is such to preclude the possibility of shutting off the communication of any boiler with the safety valve or valves employed.

"The use of two safety valves may be allowed on any boiler, provided the combined area of such valves is equal to that required by rule for one such valve. Whenever the area of a safety valve, as found by the rule of this section, will be greater than that corresponding to 6 inches in diameter, two or more safety valves, the combined area of which shall be equal at least to the area required, must be used.

"Where escape pipes for safety valves are installed in steam vessels after July 1, 1910, the area of such pipes shall equal the combined area of all valves to which such pipes are connected.

"The seats of all safety valves shall have an angle of inclination of 45° to the center lines of their axes.

LEVER SAFETY VALVES.

"All common lever safety valves to be hereafter applied to the boilers of steam vessels must be constructed in material, workmanship, and principle according to the requirements for a safety valve referred to in this section. When this construction of a safety valve is applied to the boilers of steamers navigating rough waters, the link may be connected direct with the spindle of the valve: *Provided, always*, That the fulcrum or points upon which the lever rests are made of steel, knife or sharp edged, and hardened; in this case the short end of the lever should be attached directly to the valve casing. In all cases the link requires but a slight movement not exceeding one-eighth of an inch.

The following are the rules in force in Massachusetts since 1909:

"Each boiler shall have one or more safety valves.

"The minimum size of a direct spring-loaded safety valve shall be governed by the pressure allowed, as stated in the certificate of inspection, and by the grate area of the boiler, subject to the following conditions and as shown by the accompanying table.

"Condition A.—A single boiler, of two or more boilers connected to a common steam main and allowed the *same pressure*: the minimum size of safety valve for each boiler shall be governed by the pressure allowed, as stated in the certificate of inspection, and by the grate area of the boiler.

"Condition B.—When two or more boilers, which are allowed *different pressures*, are connected to a common steam main, the minimum size of each safety valve shall be governed by the pressure allowed, as stated in the certificate of inspection, and by the grate area of the boiler; and all safety valves *shall be set* at a pressure not exceeding the lowest pressure allowed. The aggregate valve area shall not be less than that required for the aggregate grate area, based on the lowest pressure allowed as shown by the table. (Table No. 56.)

Table No. 56

TABLE OF AREAS OF GRATE SURFACES, IN SQUARE FEET, FOR DIRECT SPRING-LOADED SAFETY VALVES.

Maximum Pressure allowed per Square Inch on the Boiler		$W=\frac{75}{3600}$ P= 40 A= .401	$W=\frac{100}{3600}$ P= 65 A= .329	$W=\frac{160}{3600}$ P= 115 A= .297	$W=\frac{160}{3600}$ P= 140 A= 244	$W=\frac{200}{3600}$ P= 190 A= .224	$W=\frac{240}{3600}$ P= 240 A= 213
Dia. of Valve Ins.	Area of Valve in Sq. Ins.	Zero to 25 Lbs.	Over 25 to 50 Lbs.	Over 50 to 100 Lbs.	Over 100 to 140 Lbs.	Over 150 to 200 Lbs.	Over 200 to Lbs.
1	.7854	2.00	2.50	2.75	3.25	3.50	3.75
1¼	1.2272	3.25	4.00	4.25	5.00	5.50	5.75
1½	1.7671	4.50	5.50	6.00	7.25	8.00	8.50
2	3.1416	8.00	9.75	10.75	13.00	14.00	15.00
2½	4.9087	12.50	15.00	16.50	20.00	22.00	23.00
3	7.0686	17.75	21.50	24.00	29.00	31.50	33.25
3½	9.6211	24.00	29.50	32.50	39.50	43.00	45.25
4	12.5660	31.50	38.25	42.50	51.50	56.00	59.00
4½	15.9040	40.00	48.50	53.50	65.00	71.00	74.25
5	19.6350	49.00	60.00	66.00	80.00	88.00	92.25

"When the conditions exceed those on which the table is based, the following formula shall be used:

$$A = \frac{W\ 70}{P} \times 11.$$

A = area of direct spring-loaded safety valve in square inches per square foot of grate surface.

W = weight of water in pounds evaporated per square foot of grate surface per second.

P = pressure (absolute) at which the safety valve is set to blow.

"If more than one safety valve is used, the minimum combined area shall be in accordance with the table.

"Each safety valve shall have full-sized direct connection to the boiler, and when an escape pipe is used it shall be full-sized and fitted with an open drain, to prevent water lodging in the upper part of safety valve or escape pipe. When a boiler is fitted with two safety valves on one connection, this connection to the boiler shall have a cross-sectional area equal to or greater than the combined area of the two safety valves. No valve of any description shall be placed between the safety valve and the boiler, nor on the escape pipe between the safety valve and the atmosphere. When an elbow is placed on a safety valve escape pipe it shall be located close to the safety valve outlet, or the escape pipe shall be securely anchored and supported.

"Safety valves having either the seat or disc of cast iron shall not be used.

"Safety valves hereafter installed on boilers shall not exceed five inches in diameter, and shall be the direct spring-loaded type, with seat and bearing surface of the disc inclined at an angle of about forty-five degrees to the center line of the spindle; designed with a substantial lifting device so that the disc can be lifted from its seat with the spindle, not less than one-eighth the diameter of the valve, when the pressure on the boiler is seventy-five per cent of that at which the safety valve is set to blow."

"Condition C.—When two or more boilers, which are allowed *different pressures*, are connected to a common steam main, and all safety valves *are not set* at a pressure not exceeding the lowest pressure allowed, the boiler or boilers allowed the lower pressures shall each be protected by a safety valve or valves placed on the connecting pipe to the steam main; the area or combined area of the safety valve or valves placed on the connecting pipe to the steam main shall not be less than the area of the connecting pipe, except when the steam main is smaller than the connecting pipe, when the area or combined area of safety valve or valves placed on the connecting pipe shall not be less than the area of the steam main. Each safety valve placed on the connecting pipe shall be set at a pressure not exceeding the pressure allowed on the boiler it protects.

ADAMS BAG CO., CHAGRIN FALLS, O., CONTAINS 1200 H. P. OF HEINE BOILERS.

SUPERHEATERS.

THE question as to the proper location in which to place the superheating device has received a good deal of attention and been the subject of a great deal of experiment, but still remains perhaps a matter of discussion. First there is the possible location of the superheater in the main flue where it is exposed to the gases of combustion after they have left the boiler and are to be allowed to escape. At first thought this location seems attractive from the fact that any heat obtained in this way is a direct saving and that the superheating would cost nothing. Further consideration, however, shows that in a properly designed and operated plant practically no superheating at this point is possible for the reason that with a boiler operating under 150 lbs. pressure good practice would call for a release of the combustion gases at a temperature not much exceeding 500°F., which temperature is necessary to maintain a natural chimney draft sufficiently strong to burn a common grade of bituminous coal. Again it will be found that while existing conditions may be such as to make it possible to install the superheater in the flue and show a small increase in economy due to the increase in temperature, yet, by placing an economizer in the same location, through which the feed water may be passed on its way to the boiler, a much greater gain would result. The reason for this is that the transfer of heat depends upon the difference of temperatures. This difference in the case of an attempt to superheat the steam would be only 100°F. to 200°F., while in the case of feed water it would be from 200°F. to 400°F., so that the saving due to an economizer would be several times greater than could possibly result from the use of the superheater.

A much used location for a superheater is inside the boiler setting at a point, in a water tube boiler, between the tubes and the shell. With this arrangement the steam is passed from the boiler, through the superheater into the main steam piping, to the engines. The superheater at this point is exposed to a very high temperature and when starting up a cold boiler must be flooded with water until the boiler is generating steam freely. This flooding unquestionably causes a deposition of scale and at a location where it is impossible to be removed. The flooding and draining of the superheater is in no sense a difficult operation, but still it is one more operation to be performed when cutting a boiler into and out of service and best avoided if possible. Of course any superheat obtained at this location is obtained from the fuel burned in the furnace and the consumption of fuel will inevitably be correspondingly increased.

Another plan is to place the superheater higher up but still within the boiler setting and entirely separated from the main gas passages. A

small quantity of hot gas is conducted from the furnace or combustion chamber through a small duct in the walls, to this superheater chamber where it is brought into intimate contact with the superheating surfaces, afterward discharging into the main passage. By manipulating a damper the flow of gas is controlled to suit the degree of superheat desired. By using thermostatic control a more uniform superheating effect may be obtained than in any other way except possibly with the separately fired plan. The steam connection may or may not be arranged to by-pass the superheater.

Still another practice and one for which there are many arguments, is to place the superheater outside the boiler entirely and over a separately fired furnace, passing either the whole or only a portion of the steam through it. In a large installation where the superheater would be of sufficient size to warrant separate attention, the independently fired superheater will give good economy. In a plant consisting of only one or two boilers the superheater would necessarily be quite small and might require more care than would be justified for its operation, as it would be necessary to watch it very closely. Either gas or oil should be used for fuel since they may be quickly and accurately controlled. Unless so handled it is quite uncertain whether the total efficiency of the steam plant would be increased at all and if such a superheater were placed where it would receive only average attention it is probable that its use would be unsatisfactory.

In line with the foregoing we may divide the essential requisites for good design into three general classes. First, proper location for superheating effect; Second, accessibility for cleaning and repairs; Third, safety and durability.

PROPER LOCATION FOR SUPERHEATING EFFECT.

The rate of absorption of heat in a superheater depends directly upon the difference in temperature between the hot gases and the steam. The less this difference the greater the amount of absorbing surface required for a given degree of superheat. The superheater therefore should be so placed that the heating gases are as near furnace temperature as practicable. Superheat in steam requires the burning of fuel and is not obtained without extra cost, contrary to the rather prevalent opinion. It is desirable to have the device so arranged that the temperature of the steam can be controlled, and to do this there must be some way of regulating the quantity of the heating medium, which means that the apparatus must be placed elsewhere than in the path of the boiler gases. This is advisable also because of the added resistance and con-

sequent reduction of draft due to the presence of the superheater in the path of the products of combustion.

ACCESSIBILITY FOR CLEANING AND REPAIRS.

Where solid fuels are used there will always be greater or less accumulations of soot and dust on the superheater, especially if combustion is not perfect. As both soot and dust are excellent non-conductors of heat, in order to maintain the superheater at the point of its highest efficiency its exterior surfaces must be kept free from such substances. Smooth surfaces are preferable to any others, as they are more readily cleaned. The easier cleaning devices are to manipulate and the more effective they are, the more certain it is that they will be used and that the efficiency of the superheater will be maintained. Every part of the surfaces must be reached and that without necessitating extensive openings into the setting. Unless flooding is necessary the interior of the superheater cannot become covered with a deposit of any sort, but where water is introduced and heat applied there must inevitably be a gradual accretion that will in time have to be removed. If no means for doing this are provided burned tubes will be the result with damages and an extensive repair bill to pay. It cannot be expected that any apparatus subject to high temperatures will last indefinitely without attention and repairs of some sort. It is highly desirable therefore to anticipate such needs by making it possible to minutely inspect all parts without difficulty and to easily make such slight adjustments as will tend to avoid extensive repairs, and when such extensive work is needed to do it without excessive cost or loss of time.

SAFETY AND DURABILITY.

Due to the very nature of the service, the boilers receive the most severe treatment of any part of a power plant, and owing to the low specific heat and slow heat absorbing qualitites of steam, the superheater is even less favored than the boiler. It should therefore be constructed only of such material and in such a way as will best resist the action resulting from varying temperature in the several parts and possible excessive temperature of the metal. Undoubtedly a non-fracturable metal and seamless hot or cold drawn tubing of small diameter, make the best combination of materials for this use, when so designed that the expansion and contraction movements will not have an appreciable effect on the joints and seams. If care be taken to use only the best of their respective kinds both a safe and durable apparatus will result.

BETZ BUILDING, PHILADELPHIA, PA.,
CONTAINS 750 H. P. OF HEINE BOILERS.

CHIMNEYS, BREECHINGS AND DRAFT.

THE object of the chimney is to create draft and to carry off the waste products of combustion. The pressure or intensity of the draft is due to the difference in weight of the column of the hot gases inside the chimney and an equal column of the outside air.

The amount of coal which can be burned per square foot of grate per hour depends directly upon the intensity of the draft and it is therefore extremely important that the chimney be designed for the required conditions.

Let H = height of the chimney in feet.
T_0 = absolute temperature of air at 32°F.
T_1 = absolute temperature of the gases inside the chimney.
T_2 = absolute temperature of the external air.
W = weight of one cubic foot of air at 32°F.
W_1 = weight of one cubic foot of the chimney gases at 32°F.

Then the weight of one cubic foot of the chimney gas at the given temperature will equal: $W_1 \frac{T_0}{T_1}$ at 14.7 pounds per square inch atmospheric pressure, and a column H feet high and one square foot in cross-section will weigh:

$$H \times W_1 \frac{T_0}{T_1}$$

The weight of one cubic foot of the external air at the given temperature will equal:

$$W \frac{T_0}{T_2}$$

A column H feet high and one square foot in cross-section will weigh:

$$H \times W \frac{T_0}{T_2}$$

The theoretical pressure of the draft in pounds per square foot will be the difference of these two weights or:

$$D = H \left(W \frac{T_0}{T_2} - W_1 \frac{T_0}{T_1}\right)$$

If $T_0 = 491.6$, $W = .0807$, $W_1 = .084$ on the basis of 300 cubic feet of air used per pound of coal, then

$$D = H\left(.0807 \frac{491.6}{T_2} - .084 \frac{491.6}{T_1}\right)$$

$$= H\left(\frac{39.67}{T_2} - \frac{40.29}{T_1}\right)$$

or reducing D to pressure in inches of water

$$D_1 = H\left(\frac{7.63}{T_2} - \frac{7.94}{T_1}\right)$$

If we consider that 50% excess air will be required or 225 cu. ft. per lb. of coal, W_1 will equal .085 and the formula becomes

$$D_1 = H\left(\frac{7.63}{T_2} - \frac{8.03}{T_1}\right)$$

Table No. 57

DENSITY AND VOLUME OF AIR AND CHIMNEY GASES AT VARIOUS TEMPERATURES.

Air			Chimney Gases					
t	v	d	t	d	t	d	t	d
0	11.581	.08635	200	.06334	430	.04697	660	.03732
5	11.706	.08542	210	.06240	440	.04644	670	.03699
10	11.832	.08451	220	.06148	450	.04593	680	.03667
15	11.958	.08362	230	.06059	460	.04543	690	.03635
20	12.084	.08275	240	.05972	470	.04494	700	.03604
25	12.210	.08190	250	.05888	480	.04447	710	.03573
30	12.336	.08165	260	.05806	490	.04400	720	.03542
32	12.387	.08073	270	.05727	500	.04354	730	.03513
35	12.463	.08023	280	.05649	510	.04309	740	.03483
40	12.589	.07944	290	.05574	520	.04257	750	.03454
45	12.715	.07865	300	.05500	530	.04222	760	.03426
50	12.841	.07788	310	.05429	540	.04180	770	.03398
55	12.967	.07712	320	.05359	550	.04138	780	.03370
60	13.093	.07638	330	.05291	560	.04098	790	.03344
62	13.143	.07609	340	.05225	570	.04058	800	.03317
65	13.219	.07565	350	.05161	580	.04020	900	.03072
70	13.345	.07493	360	.05098	590	.03980	1000	.02863
75	13.471	.07423	370	.05037	600	.03943	1100	.02679
80	13.597	.07354	380	.04976	610	.03906	1200	.02518
85	13.723	.07287	390	.04918	620	.03870	1300	.02374
90	13.849	.07220	400	.04861	630	.03835	1400	.02247
95	13.975	.07155	410	.04805	640	.03799	1500	.02132
100	14.101	.07091	420	.04750	650	.03765	1800	.01849
110	14.353	.06966					2000	.01699

t = temperature in degrees Fahrenheit.
v = volume in cubic feet.
d = weight of one cubic foot.

The direct connection that can be made from Heine boilers to the stack, together with a minimum loss by friction through the gas passages of the boiler, conduces to the maximum intensity of draft in the furnace. It is draft intensity that determines the amount of fuel which can be burned.

Table No. 58

THEORETICAL DRAFT, PRESSURE IN INCHES OF WATER.
CHIMNEY 100 FEET HIGH.

Temp. in Chimney	Temperature of external air. Bar. 14.7 lbs. per sq. in.										
	0	10	20°	30°	40°	50°	60°	70°	80°	90°	100°
200	.456	.421	.387	.355	.323	.294	.265	.237	.210	.184	.160
225	.500	.465	.431	.399	.368	.338	.309	.281	.254	.229	.204
250	.542	.507	.473	.440	.409	.379	.350	.323	.296	.270	.245
275	.579	.544	.510	.478	.446	.417	.388	.360	.333	.307	.283
300	.615	.578	.546	.513	.482	.452	.423	.395	.369	.343	.318
325	.648	.613	.579	.546	.515	.485	.456	.429	.402	.376	.341
350	.679	.644	.610	.578	.546	.517	.488	.460	.433	.407	.383
375	.709	.673	.639	.607	.576	.546	.517	.489	.463	.437	.412
400	.736	.701	.667	.635	.604	.574	.545	.517	.490	.465	.440
450	.787	.752	.718	.685	.654	.624	.595	.568	.541	.515	.490
500	.833	.797	.763	.731	.700	.670	.641	.613	.587	.561	.536
550	.874	.838	.804	.772	.731	.711	.682	.654	.628	.602	.577
600	.911	.875	.841	.809	.778	.748	.719	.691	.665	.639	.614

For any other height multiply the tabular value by $\frac{H}{100}$, where H equals the height in feet.

For any other pressure multiply the tabular pressure by $\frac{P}{14.7}$, where P equals the atmospheric pressure in lbs. per sq. in.

Practically it has been found that rational formulae for the area or height of chimneys do not give good results, due to the fact that the constants to be used vary with the area of the air spaces through the grate, the kind of coal, and the rate of combustion. A constant determined for a grate with 25% to 33% air space and a consumption of 8 lbs. to 15 lbs. of coal will not be suitable for a grate having 50% air space and burning 20 lbs. to 40 lbs. of coal. It is therefore customary to use empirical formulae based on good practice and the following are some of the best known:

SMITH

$$A = \frac{0.0825\ F}{\sqrt{h}}$$

$$h = \left(\frac{0.0825\ F}{A}\right)^2$$

KENT

$$E = \frac{0.06\ F}{\sqrt{h}}$$

$$h = \left(\frac{0.06\ F}{E}\right)^2$$

GALE

$$A = 0.07\ F^{\frac{2}{3}}$$

$$h = \frac{180}{t}\left(\frac{F}{G}\right)^2$$

In which A = area of the stack in square feet.
h = height of the stack in feet.
F = pounds of coal burned per hour.
G = grate area in square feet.
E = A — $0.6\sqrt{A}$.
t = stack temperature.

Gale's constants modified so that $h = \frac{120}{t}\left(\frac{F}{G}\right)^2$ give better results according to modern practice.

The formulae showing an interdependence of height and areas may lead to absurdities. It is better therefore to determine the height with a formula such as the modified Gale formula and then determine the area by Kent's.

Practical and local considerations generally fix the height required. The chimney must be higher than the surrounding buildings or hills, else whenever the wind comes from the direction of the higher object, the draft will be seriously impaired.

T. F. J. Maguire in the Engineering Magazine for February, 1910, states that the draft on a water tube boiler is divided as follows:

DRAFT REQUIRED IN THE FURNACE.

Kind of coal	Pounds of dry coal burned per square foot of grate per hour.						
	15	20	25	30	35	40	45
Eastern bituminous coals............	.12	.16	.20	.27	.34	.42	.52
Western bituminous coals...........	.15	.20	.25	.33	.42	.52	.65
Semi-bituminous coals................	.15	.20	.28	.37	.48	.60	.80
Anthracite buckwheat No. 1 and larger	.45	.70	1.00				
Anthracite buckwheat No. 2 and No 3	.75	1.30					

An allowance of 0.3 inch of water column seems to be ample for draft loss in boiler settings when boilers are developing not over 25% in excess of rated capacity, and 0.4 inch of water column for an overload of 50%.

The loss in the breechings depends upon their length, the number of turns, and the cross-sectional area. The material also has an influence upon the draft, the loss in a brick flue being about one-third more than in a steel or iron flue. For circular steel or iron breeching, having an area equal to the stack or larger, it is customary to allow 0.1 inch loss of draft per 100 feet of length. For each right angled turn an additional draft of 0.05 inch of water column.

For square or rectangular breechings (if adjacent sides do not differ more than in the ratio of 2 to 1) of steel or iron, the allowance given above for circular flues should be increased 25%. For brick or brick lined flues increase the above figures 30%.

If we assume that, in any well designed stack, the available draft pressure is equal to 80% of the theoretical we may substitute this value

in the formula for the pressure and solve for the requisite height. Then having determined the necessary height we may solve for the area by Kent's formula as before.

In Table No. 59 appropriate heights and areas of chimneys are given for powers from 75 to 3100 horsepower; based on an assumed evaporation of 7 lbs. of water per lb. of coal, equivalent to 5 lbs. coal per H. P. per hour.

Table No. 59

CHIMNEY HEIGHTS AND AREAS.

Area in Square Feet	Dia. In.	Height in Feet												
		75	80	85	90	95	100	110	120	130	140	150	175	200
		Commercial Horse Power												
3.14	24	75	78	81										
3.69	26	90	92	95	98									
4.28	28	.....	106	110	114	117	120							
4.91	30	.....	122	127	130	133	137							
5.59	32	.....	.....	144	149	152	156	164						
6.31	34	.....	.....	162	168	171	176	185						
7.07	36	.....	.....	.....	188	192	198	208	215					
8.73	40	.....	.....	.....	.....	237	244	257	267	279				
10.56	44	.....	.....	.....	.....	287	296	310	322	337				
12.57	48	.....	.....	.....	.....	.....	352	370	384	400	413			
15.90	54	.....	.....	.....	.....	.....	445	468	484	507	526			
19.63	60	.....	.....	.....	.....	.....	.....	577	600	627	650	672		
23.76	66	.....	.....	.....	.....	.....	.....	697	725	758	784	815		
28.27	72	.....	.....	.....	.....	.....	.....	.....	862	902	932	969	1044	
38.48	84	.....	.....	.....	.....	.....	.....	.....	1173	1229	1270	1319	1422	
50.27	96	.....	.....	.....	.....	.....	.....	.....	.....	1584	1660	1725	1859	1983
63.62	108	.....	.....	.....	.....	.....	.....	.....	.....	2058	2102	2181	2352	2511
78.54	120	.....	.....	.....	.....	.....	.....	.....	.....	.....	2596	2693	2904	3100

If there are a large number of boilers in a plant it is frequently better to have a number of small chimneys than a single large one. If there is only one chimney, then it should be located as near the center of distribution as possible.

The breeching should be as short and direct as possible. If a number of boilers lead into the same breeching, the breeching should be designed for the required capacity near the stack and then gradually decrease in size as the number of boilers leading into it grows less.

The shape and location of the uptake for the spent gases from a Heine Boiler is such that a simple and inexpensive breeching can be designed to meet the conditions imposed by practically any boiler room arrangement. Usually it can be placed above the boiler where it is out of the way as far as possible yet readily accessible for cleaning. *See page 160.*

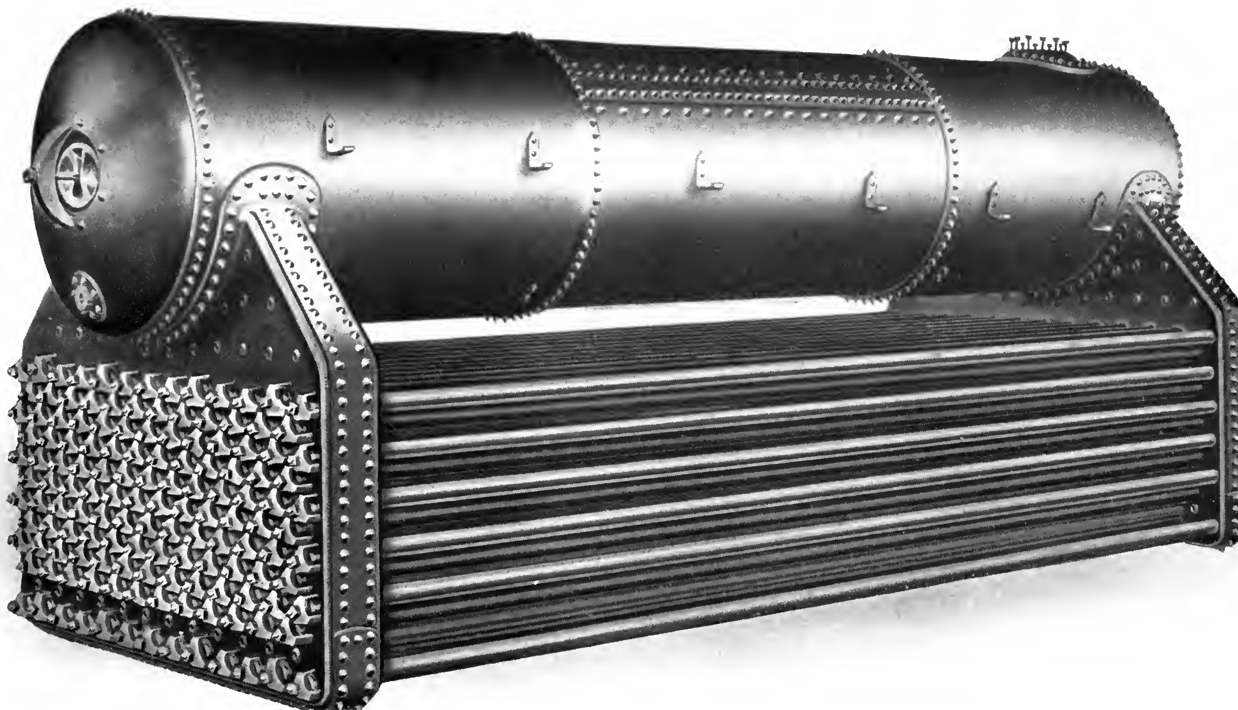


Fig. 3.

THE HEINE BOILER.

THE HEINE BOILER.

THE Heine Boiler is a modern boiler in every sense of the word, and was designed and arranged so as to comply to the greatest possible extent with all those principles enunciated in the general subject of Boilers, page 123. This end has been arrived at from years of experiment and improvements of which these principles have been the basis. With each succeeding year our success has been more pronounced and there will be no relaxation of our efforts to keep the Heine Boiler always a modern one.

That a boiler which conforms to the principles laid down cannot be cheap in first cost must be obvious. If, however, the cheapness is measured by giving due weight to these cardinal conditions it must be evident that a high priced boiler may easily be the cheapest in the long run. We do not build a cheap boiler, and cannot, and do not care to compete with those that do. A continuously growing business has convinced us that it is not necessary, and that the demand for a boiler of the best quality is also growing.

CONSTRUCTION.

The Heine Boiler may be divided into three main parts, these being the shell, waterlegs, and tubes (Fig. 3).

The shell is cylindrical in form, varying in diameter from 30 inches to 48 inches, and in length from about 17 feet to 21.5 feet, depending upon the size of the boiler. This shell is made up of three sheets riveted in accordance with the generally accepted rules. The longitudinal seams are of the double strap butt joint type while the round about seams are all lapped with single or double riveting. The design of the riveting is dependent in all cases upon the pressure to be carried. The heads of the shells are dished to a radius equal to the diameter of the shell so as to require no

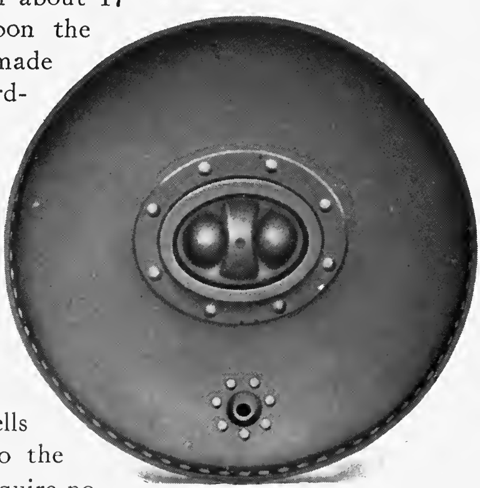


Fig. 4a

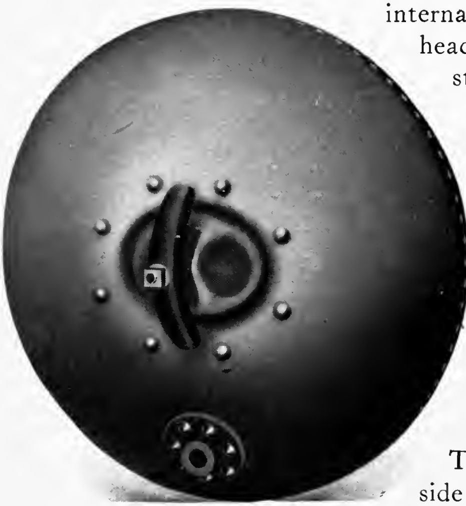


Fig. 4b

internal staying. Both front and rear heads are machine made with pressed steel flanges for the feed and blow-off connections. The rear head is provided with a flanged-in reinforced manhole (Fig. 4a) with a light and stiff pressed steel cover and yoke (Fig. 4b). At the top of the shell near the front end is cut the main steam outlet, a pressed steel saddle, (Fig. 6, page 157) being strongly riveted to the shell for the purpose of attaching the steam tee. The standard form of tee has flanged side and top outlets. Either one of these may be used for the main steam connection, the safety valve being attached to the other. In the bottom of the shell near each end is cut the throat opening for the internal connection to the waterleg. To compensate for the metal cut away, forged steel throat stays (Fig. 7, page 157) bridging these openings are riveted on when the waterlegs are attached. Inside and near the bottom of the shell and parallel thereto is fastened a sheet steel mud drum, which is entirely closed with the exception of a small opening at the top near the front end. The feed pipe which passes through the front head of the shell enters the front end of the mud drum near the bottom, while the blow-off connection which passes through the bottom of the rear head of the shell connects with the back end of the mud drum near the bottom. The theory of the operation of the mud drum will be described later.

Over the throat opening at the front end slanting upwardly to the rear is placed a sheet iron deflection plate. The deflection plate is closely fitted to the front head and to that portion of the circumference of the shell with which it comes in contact. It extends several feet back of the throat opening and within a few inches of the top of the shell. Inside of the shell, just beneath the steam opening, and above the deflection plate is fastened the dry pan which is a shallow sheet iron box, in the sides of which are a large number of perforations. (Fig. 12 page 160)

To each side of the exterior of the shell is attached a series of hooks which support the tile bars, the function of which will be described farther on. The waterlegs are made of two plates, termed respectively the tube sheet and the hand hole sheet. These plates are machine flanged, and joined together all around except at the top by a butt strap. Being

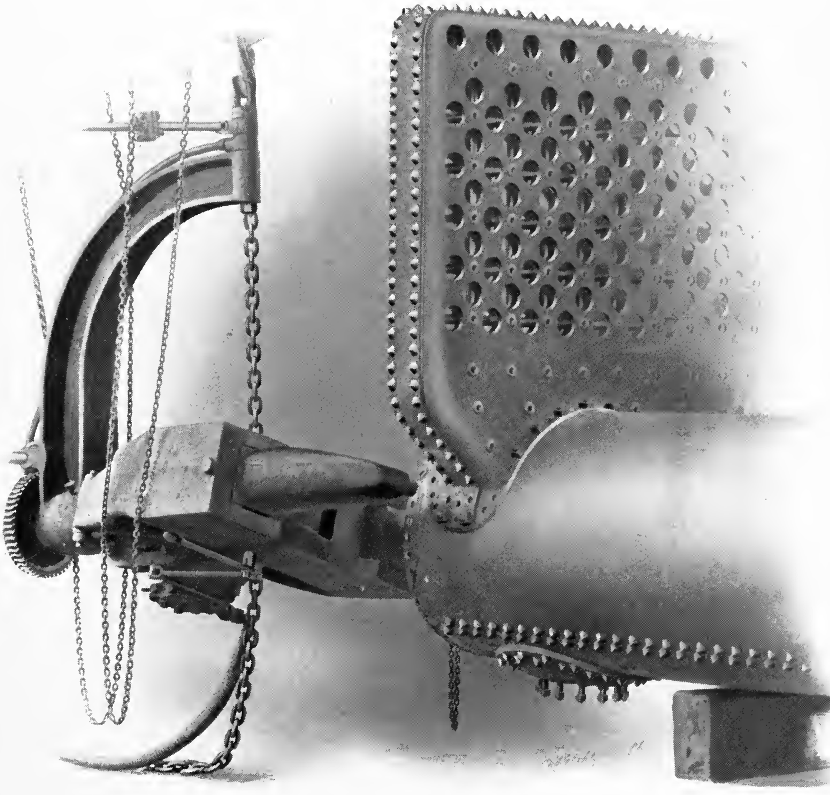


Fig. 5.

A DETAIL OF CONSTRUCTION.

flat surfaces these waterlegs require staying to withstand the internal pressure, and for this purpose hollow staybolts (Fig. 8) are used, made of carefully tested mild steel tubing manufactured specially to our specifications and carefully tested before being accepted. These are screwed into tapped holes in the two plates, the projecting ends being carefully upset on the outside. The tube holes and hand holes are carefully bored to exact diameters. The waterlegs are built complete, separately from the shell and then riveted thereto over the throat openings by hydraulic riveters (Fig. 5, page 155).

The hand holes are closed by means of strong cast iron (Fig. 9) or drop forged steel (Fig. 10a and 10b) plates which are inserted from the inside so that the steam pressure tends to make them tighter and not to loosen them as in the case of plates which are applied from the outside. These plates are held in position by means of yokes and bolts bearing against the outside of the waterleg sheet. The hand holes are round with the exception of a few at the top and bottom which are oval through which to introduce the round plates. Being round and accurately made all plates are absolutely interchangeable.

Between the two waterlegs extend the tubes which are fastened in position by being expanded with the best type of roller expanders and slightly flared to increase the holding power.

The material of which the shells and waterlegs are built is the best flange steel plate made especially to our own specifications and tested before shipment. These test reports are kept on file for customer's reference whenever desired. The tubes are made of the best mild steel, and also to our own specifications. From start to finish the work is done in our own shops, largely by hydraulically and pneumatically operated machinery, and always with the very best of materials and workmanship (Fig. 5).

The above constitutes the boiler proper, but accompanying it is an artistic front (Fig. 11, page 158) made up of substantial sheet steel and castings, together with grates, buck staves and other parts necessary to properly set the boiler ready for the brick work, also a steam gage, safety valve, water column and trimmings, and feed and blow-off valves.

SETTING AND OPERATION.

(See Fig. 12, Page 160)

When set up ready for service the Heine Boiler inclines downwardly from front to rear, one in twelve. The front end is supported on heavy cast iron columns, the rear end resting on rollers which in turn bear on

FIG. 8

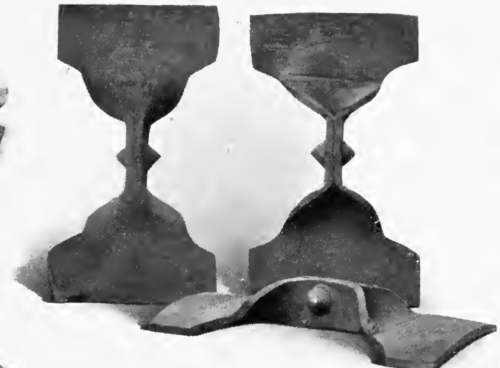


FIG. 7

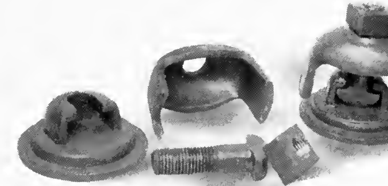


FIG 10B

FIG. 9

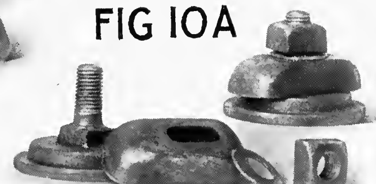


FIG 10A

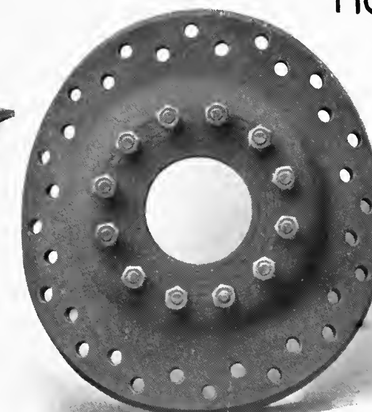


FIG. 6

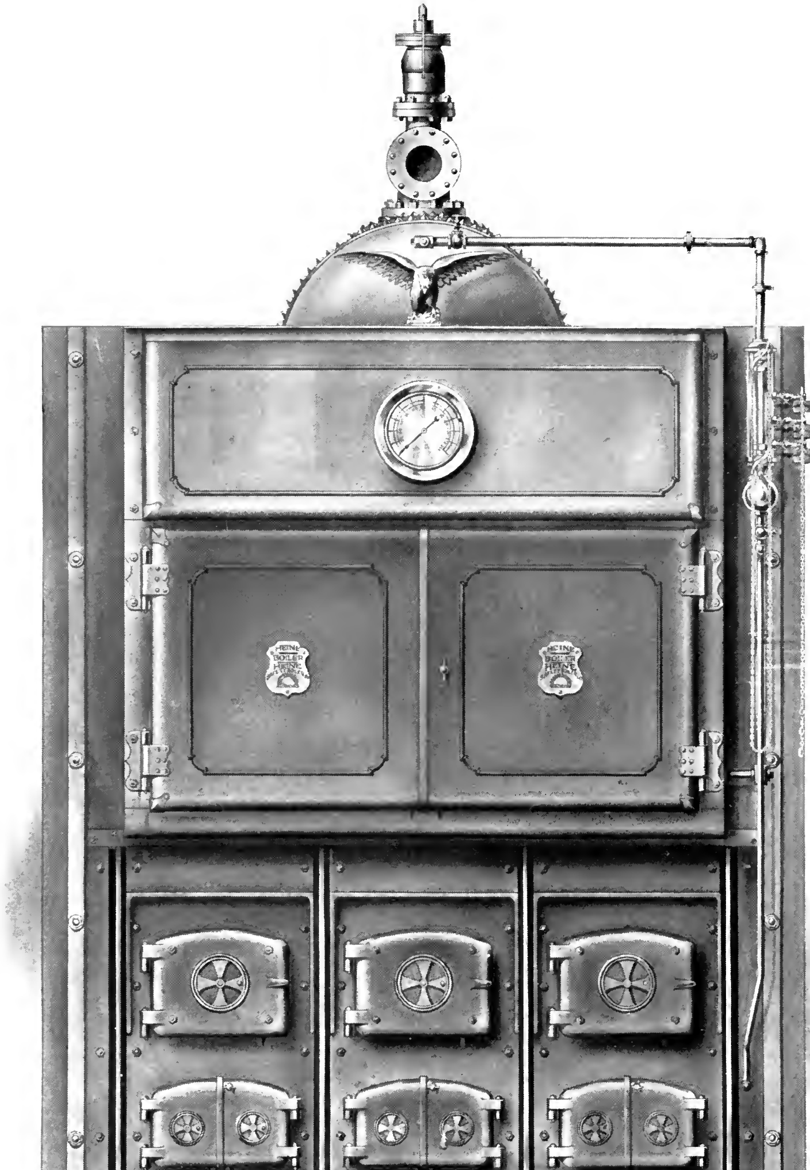


Fig. 11.

STANDARD FRONT OF HEINE BOILERS.

iron plates set in the top of the low and substantial brick wall which forms a portion of the setting. The manner in which a Heine Boiler is constructed makes this method of support the logical one and far better than hanging, since all strains due to the weight of the boiler and contents are avoided. In case, however, it is necessary to arrange the boiler so as to accommodate some stoking device stout steel brackets are riveted to the waterlegs, in turn resting on special heavy cast iron or steel columns, or an overhead support by which the boiler is suspended from above. To the cast iron columns are bolted the fire and ash door frames and other castings that make up the fire front, and behind which is built a substantial fire brick wall to pretect the whole from overheating. These castings also support the upper or ornamental front. On each side solid brick walls lined with fire brick are carried up to the height of the ornamental front and at both front and rear, returns are made which follow the curvature of the shell and waterleg, being supported by properly shaped metal supports that carry the weight of the brick work. The space between these metal supports and the boiler is packed full of asbestos fibre, thus preventing the ingress of air and any displacement of the brick work due to movements of the boiler, since everything is supported independently of the boiler and slightly away from it. The rollers, before mentioned, allow the expansion and contraction movements to take place without setting up injurious strains.

On each side of the shell cast iron plates are placed, one end resting on the side wall, the other on the tile bar hereinbefore mentioned. These plates do not extend all the way back, openings being left on each side of the shell through which the gases of combustion pass upwardly and out through the smoke connections. Over the shell is built an arch of brick to prevent radiation loss. This arch in the up-take is built of fire brick.

Supported by the boiler walls, and over the up-take openings, is placed a breeching hood which can be made of the necessary shape to connect with a breeching of whatever design may be required by the conditions under which the boiler is installed.

Longitudinal and transverse anchor rods are built into the brick work, these being secured at each end of the setting and at several points on the sides to substantial rolled steel buck staves, thus binding the whole together.

On the lower row of tubes, extending back within four or five feet of the rear end, are placed fire brick baffle tiling, and likewise on the upper row of tubes extending from the rear to within three or four feet of the front end. These together with the plates which rest on the tile bars

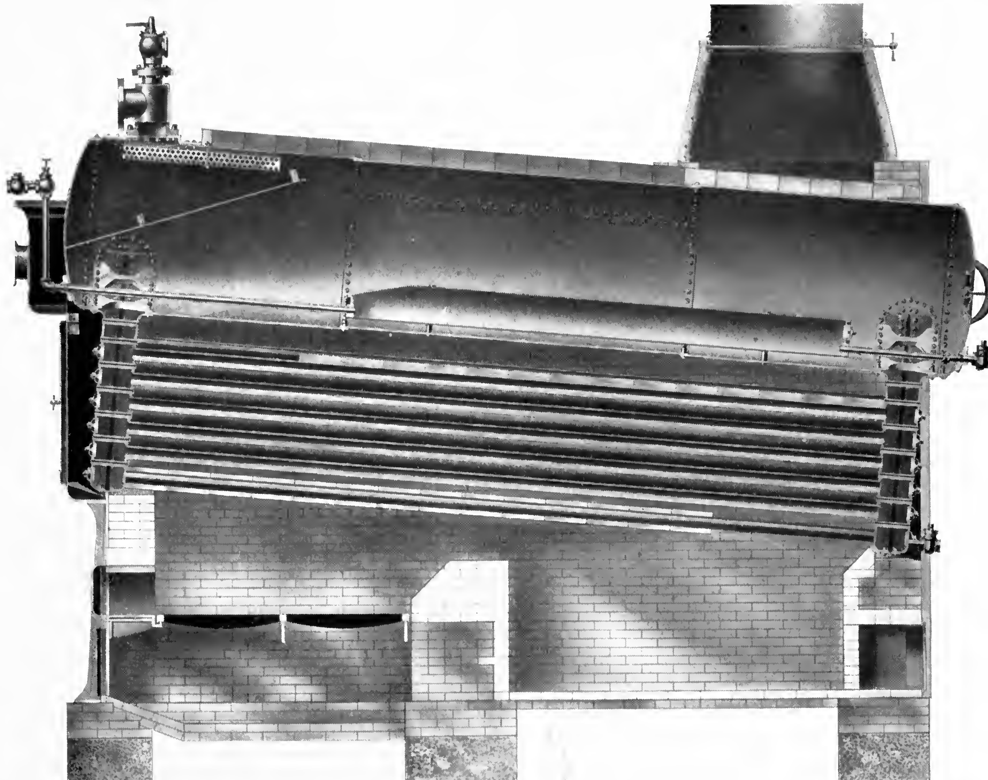
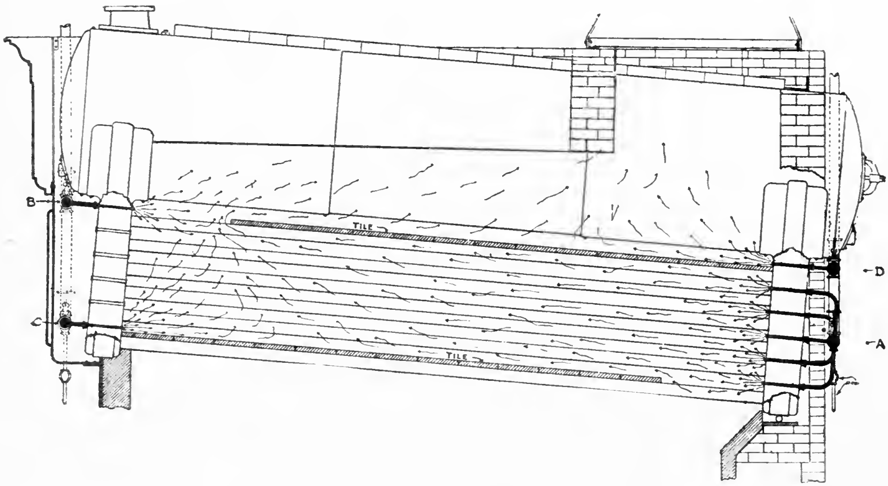


Fig. 12.

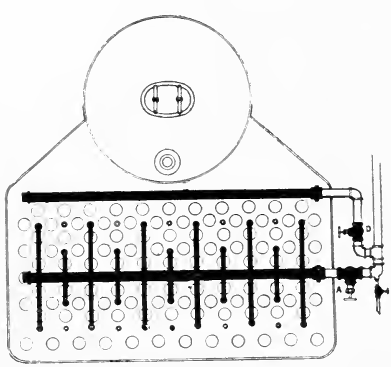
LONGITUDINAL SECTION OF HEINE BOILER AND SETTING.

above mentioned determine the path of the hot gases. Just behind the grates is placed a bridge wall only sufficiently high to hold the coal in place, thus providing ample area for the passage of the gases between the top of the bridge wall and the tubes. Our standard practice is to furnish a stationary grate although any form of shaking grate or other furnace may be substituted if desired. The gases of combustion, however, whatever type of grate or furnace may be used, pass over the bridge wall into the large combustion chamber behind it where ample time is given for the complete combustion of the various constituent gases. These then turn upward back of the lower row of tiling into the nest of tubes, thence forward parallel to the tubes, upward again into the space beneath and around the shell, thence backward and upward through the up-take into the breeching The hot gases are broken up into numberless small streams that completely encircle the tubes, this being due to the very compact arrangement of the tubes, and it is during this passage that the greater part of the heat is absorbed The gases are further cooled in passing backward under the shell.

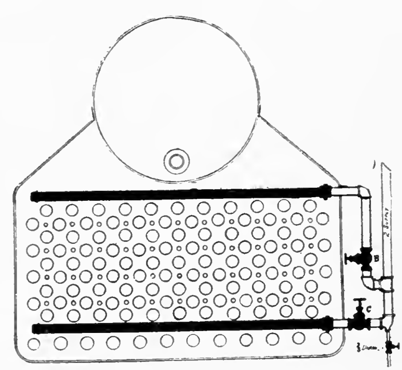
The feed water enters the boiler through the front head, passing into the mud drum, which is entirely submerged, the water level being normally at about the center of the shell midway of its length. The water in the boiler when under steam is, of course, at the same temperature as the steam. The feed water when entering is relatively much colder than the water in the boiler, and hence flows along the bottom of the mud drum, being gradually heated up by the surrounding hot water to the temperature of this water (this makes it possible to actually force the Heine Boiler with feed water of any temperature from 32° up without injury). As this movement is very slow, time is given for the deposition of such substances as may be carried in suspension and also for the precipitation of much of the scale making impurities. Being entirely without contact with the fire, there is no tendency for this sludge to become baked and hard and it may be blown off through the pipe provided from the rear of the mud drum. The feed water as it becomes hot rises and flows out in a thin sheet through the opening in the front end of the mud drum, being carried by the circulation of the water in the boiler to the rear. It will be observed that owing to the position of the boiler there is a much deeper body of water in the shell at the rear than at the front, thus providing at all times a solid body of water to keep up the supply to the tubes where the steam is made. The water descends from the shell into the rear waterleg, thence into the various tubes, passing upwardly toward the front and absorbing in its passage the heat from the gases on the outside of the tubes, bubbles of steam being formed, which pass out of the tubes, together with the unevaporated



SIDE VIEW.



REAR END.



FRONT END.

Fig. 13.

SHOWING THE APPLICATION AND ARRANGEMENT OF THE BAYER SOOT BLOWER SYSTEM.

water, into the front waterleg, thence upwardly into the shell. The large openings from the shell into the waterleg, or throat openings, while being the most constricted parts in the path of the circulating water, are so large that little or no real obstruction to a free flow is offered.

In the sectional water tube boilers from six to twelve tubes discharge into a header which is connected to the shell by a single tube of the same diameter as the others, and through which all the others must discharge. Obviously the circulation must be greatly interfered with. In the Heine Boiler the throat areas are from 2 to 4 times as large.

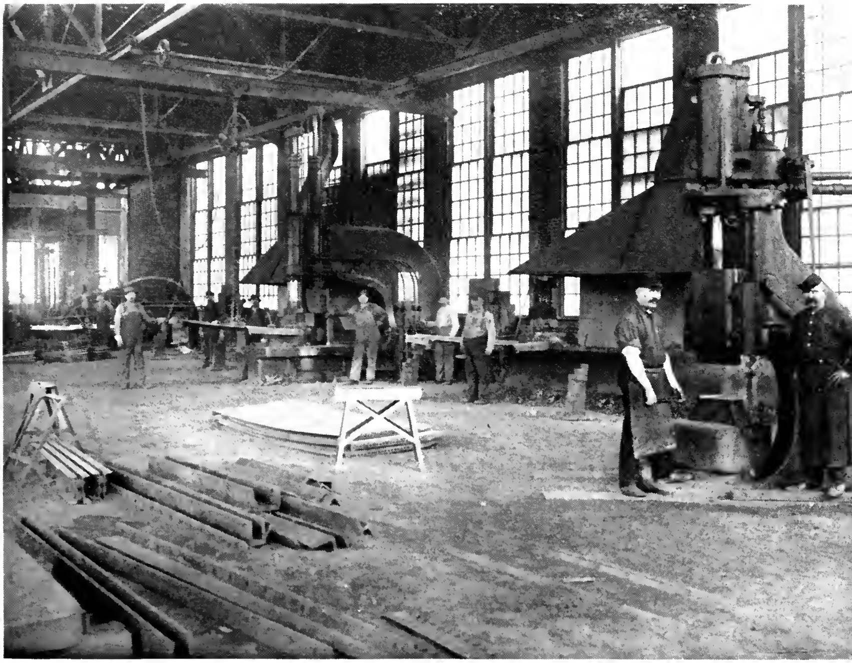
Owing to the great difference in volume caused by the expansion of the water into steam, the passage out through the waterleg is very rapid and the mixture of steam and water is thrown up with considerable force against the deflection plate, the function of which is to throw down the water allowing the steam to pass up into the steam space, thence over the upper end of the deflection plate through the holes in the dry pan to the steam outlet. Here again the larger throat areas of the Heine Boiler reduce the speed, thus giving drier steam.

At the bottom of the rear waterleg is provided a valve for the purpose of draining the boiler. The steam connection of the water column is made at the top of the front head while the water connection is made at the top of the front waterleg. The steam gauge is piped from one of the fittings of the water column connection and is fastened in a prominent position in the middle of the ornamental front.

The hollow stay bolts are utilized for the purpose of blowing accumulations of soot and dust off from the tubes. This is done by means of the Bayer Soot Blower System, which consists of a series of small nozzles inserted in the staybolts at the rear end of the boiler, with auxilliary sets of nozzles located so as to stir up accumulations in all corners. Through these nozzles are blown jets of steam, which create an intense momentary draft that dislodges and drags out all the dust and soot adhering to the surfaces to be cleaned or which obstruct the gas passages (Fig. 13.) This is done in a few minutes during the noon rest or just before or after closing down at night. Those staybolts which are not thus utilized by the soot blower nozzles are closed by means of wooden or cast iron plugs.

Cleaning doors on each side of the shell which take the place of a few of the plates above mentioned, provide means of access to the space over the upper tiling and beneath the shell so that accumulations of dust and soot at these points may be conveniently removed.

A cleaning door placed in the rear wall on which the rear waterleg rests provides means of access to the combustion chamber so that accumulations of dust at this point may be easily removed.



FLANGING DEPARTMENT, HEINE SAFETY BOILER CO. SHOP, ST. LOUIS, MO.

DRIVING STAYBOLTS IN WATERLEGS, HEINE SAFETY BOILER CO. ST. LOUIS, MO.

Through the manhole in the rear head of the shell the interior of that part of the boiler can be thoroughly inspected and any necessary attention given to the mud-drum, deflection plate, etc. Through the hand holes which are opposite each tube a stream of water may be directed into and through the tubes for the purpose of washing them out, although in doing this it is not necessary to remove all the hand hole plates; one out of every four or five giving access to the several surrounding tubes.

If, however, it is desired to scrape the tubes, each hand hole plate must be taken out to allow the introduction of the scraper. In both this and the washing-out process the hand hole plates on one end only need to be removed. Since only straight tubes are used it will easily be seen that there is no part of the interior of the boiler that cannot be reached, effectually cleaned and *visually inspected* so there is absolutely no uncertainty as to its condition. Likewise the entire exterior of the boiler can be reached for cleaning purposes and can also be inspected as to its condition. The operation of the renewing of a tube, the necessity for which is likely to occasionally arise with any boiler, is performed by loosening the ends of the tube where it is expanded into the tube-sheet, and removing same through the opposite hand hole. The new tube can then be inserted and expanded into place. Straight tubes of a commercial size are used, which can be readily obtained from any boiler maker or dealer in boiler supplies, or a few of our special quality can be carried on hand to meet possible emergencies, hence there need be no delay in making any such renewal should it become necessary.

All the cleaning operations as well as the renewal of tubes are performed by men on the outside of the boiler, standing erect, and therefore in position to efficiently do the work in a convenient, comfortable and expeditious manner.

There being no need for getting in between the rows of tubes from the sides or from above or below, these can be spaced quite closely together. The shell, also, is no higher above the tubes than is necessary to give the required area to the gas passages. Hence the whole structure is very compactly designed requiring a minimum of head room.

It will also be noted that all work about the boiler of whatever character, is performed from the front and rear, and that no openings whatever are required or made in the side walls to serve as a starting point for cracks. This permits as many boilers as may be desired being put in one battery, effecting a very material economy in floor space, reducing the cost of brick work for the boilers as well as the dimensions and consequent cost of the boiler house itself. See Page 122.

Heine Boilers may be arranged to suit the conditions of any plan. This is said advisably for with scarcely an exception every problem that has been presented has been satisfactorily solved. Owing to the infinite variety of arrangements possible it is quite impracticable to adequately illustrate the possibilities. Every type of mechanical furnace has been installed in connection with Heine boilers. It is possible and usual to place such furnaces entirely under the boiler, thus not taking up any more floor space than with hand firing. It is advantageous at times, however, to use an extension furnace or Dutch oven setting. Fig. 14 to 19 show how the various types of stokers are applied and illustrates also some departures from the usual and simplest practice. For the purpose of burning wood shaving, sawdust, tan bark, bagasse and similar fuels an extension Dutch oven is the best arrangement owing to the large furnace dimensions desirable and the convenience in feeding through the top, as illustrated in Fig. 19.

MANUFACTURING FACILITIES.

On his shop equipment depends the ability of the manufacturer to make his finished product of the highest quality of workmanship, and on it also depends his ability to promptly meet the deliveries called for by his contracts. Without the special tools required to economically perform the various operations of the manufacturing processes, both as regards the major and minor details, workmanship of the highest type cannot be executed.

Years of experience in building boilers of only one kind tend to the development of numerous devices for performing economically, expeditiously, and perfectly, numerous little details of work that cannot possibly be as well done in other ways and with cruder apparatus.

Complete equipment implies not only that required for the actual manufacturing processes but all of the necessary arrangements for promptly and cheaply handling both incoming raw material and outgoing finished product.

On pages 2 and 6 are shown general views of the two large shops owned and operated by this Company. Both plants are of about equal capacity, although the one at St. Louis is of a much better design and construction, since it was built some ten years after the one at Phoenixville, and full advantage was taken of the experience gained from the earlier plant. Both shops, however, are fully equipped with the best electrical, pneumatic and hydraulic machinery as well as with cranes and other apparatus for handling the heavy weights involved in the manufacturing of our boilers.

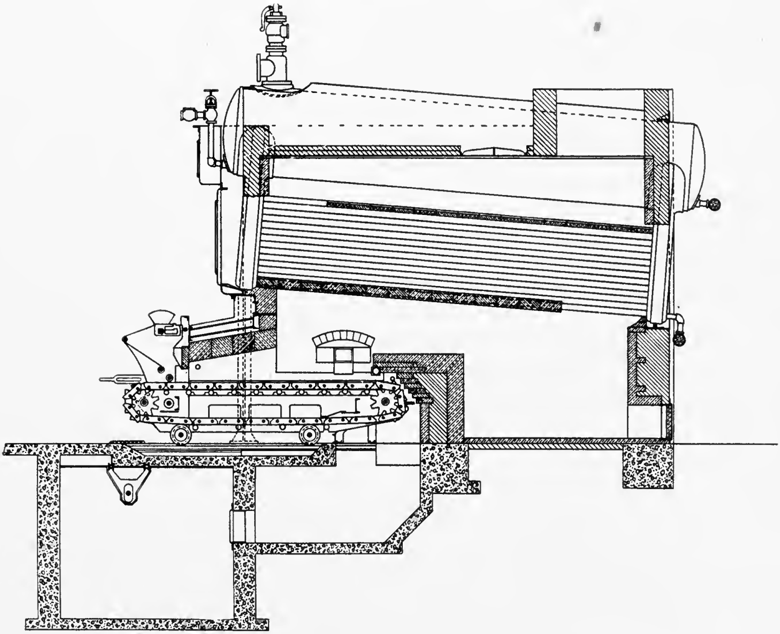


Fig. 14.

HEINE BOILER SET WITH CHAIN GRATE TYPE OF STOKER, UNDERFLOOR ASH PIT AND TUNNEL.

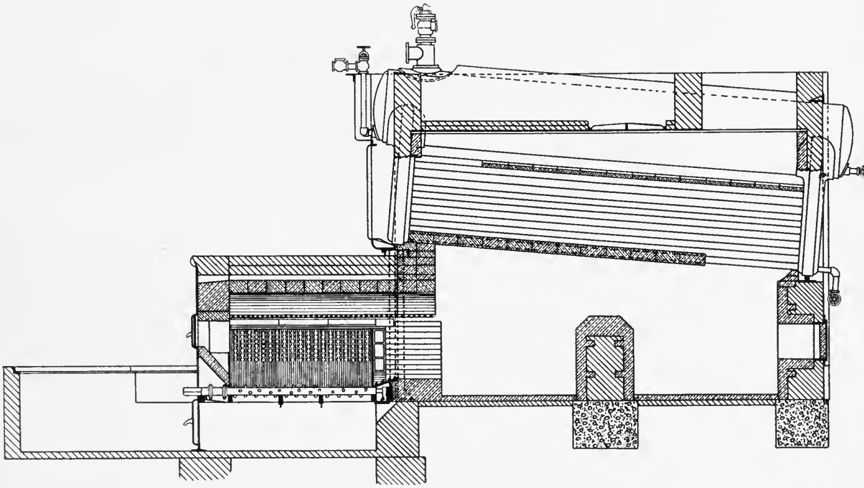


Fig. 15.

HEINE BOILER SET WITH SIDE INCLINED GRATE TYPE OF STOKER.

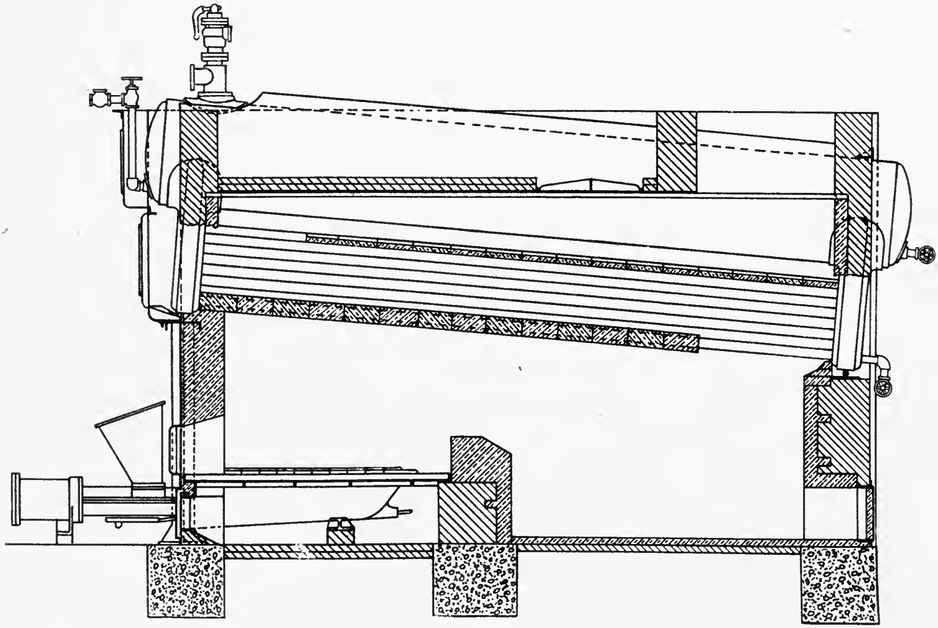


Fig. 16.

HEINE BOILER SET WITH UNDERFEED TYPE OF STOKER.

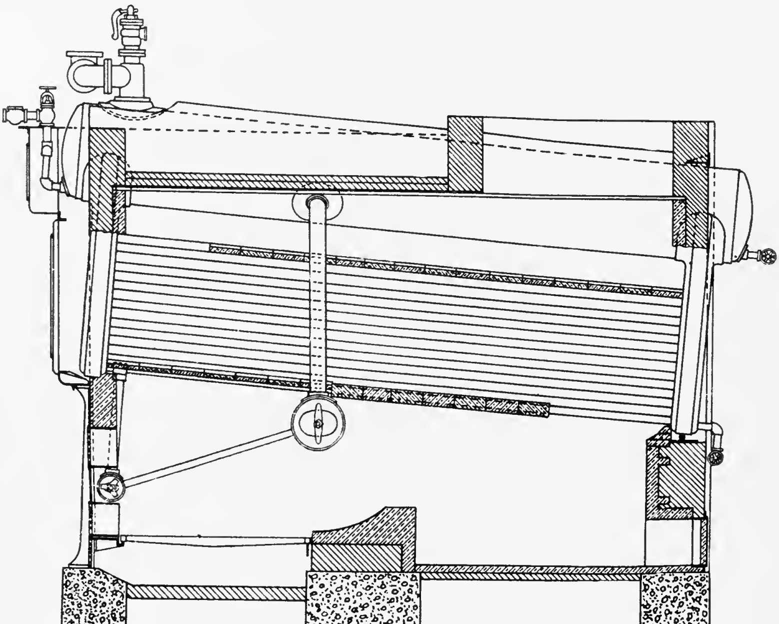


Fig. 17.

HEINE BOILER SET WITH DOWN DRAFT FURNACE.

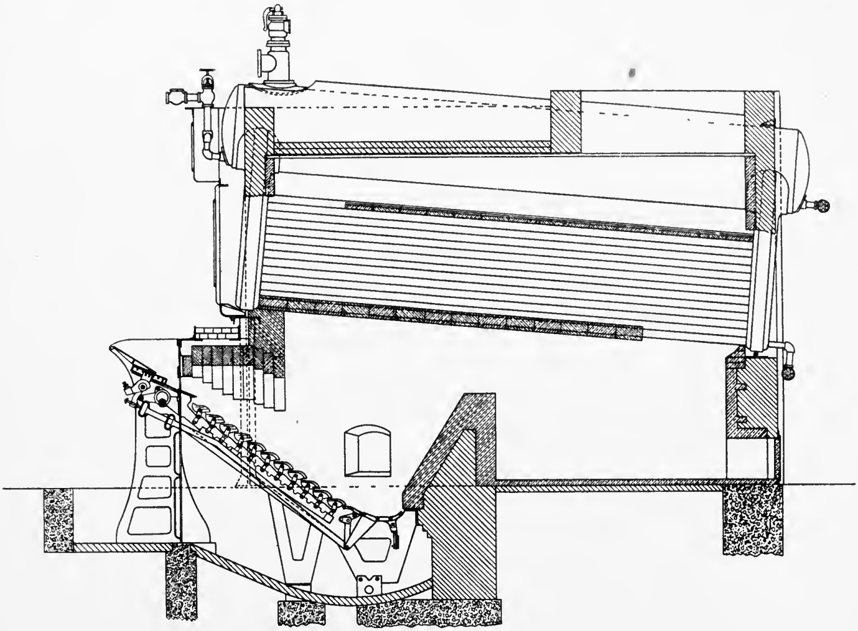


Fig. 18.

HEINE BOILER SET WITH FRONT INCLINED GRATE TYPE OF STOKER.

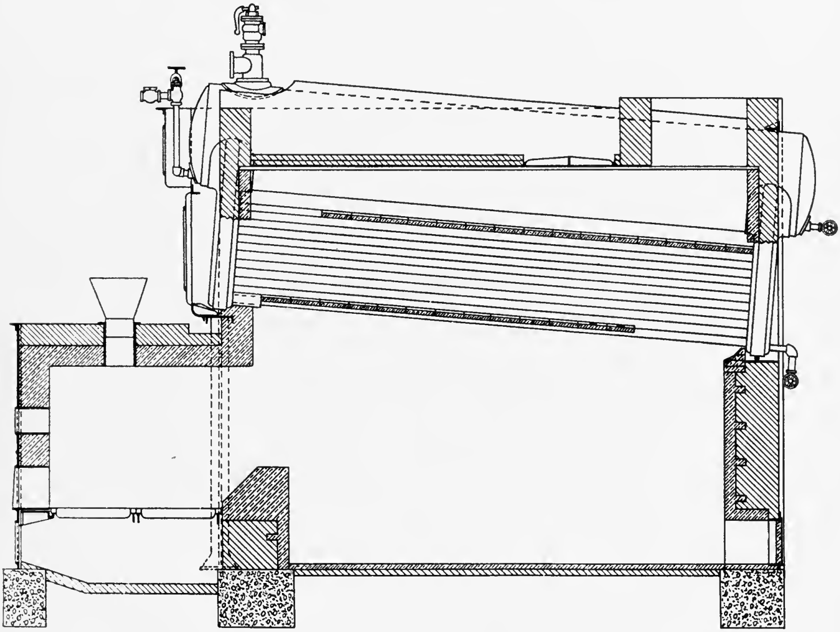


Fig. 19.

HEINE BOILER SET WITH EXTENSION OR DUTCH OVEN FURNACE. FOR BURNING SAWDUST, RICE CHAFF, BAGASSE, ETC.

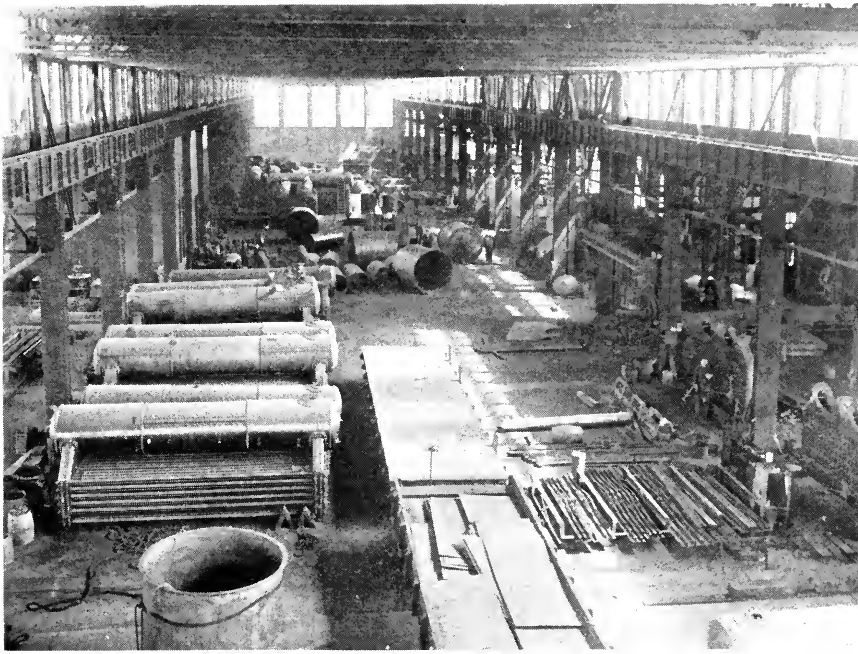
Interspersed we show herein a number of views of the St. Louis shop from which may be gathered a fair idea of the character of the plants in which our manufacturing is carried on.

IN GENERAL.

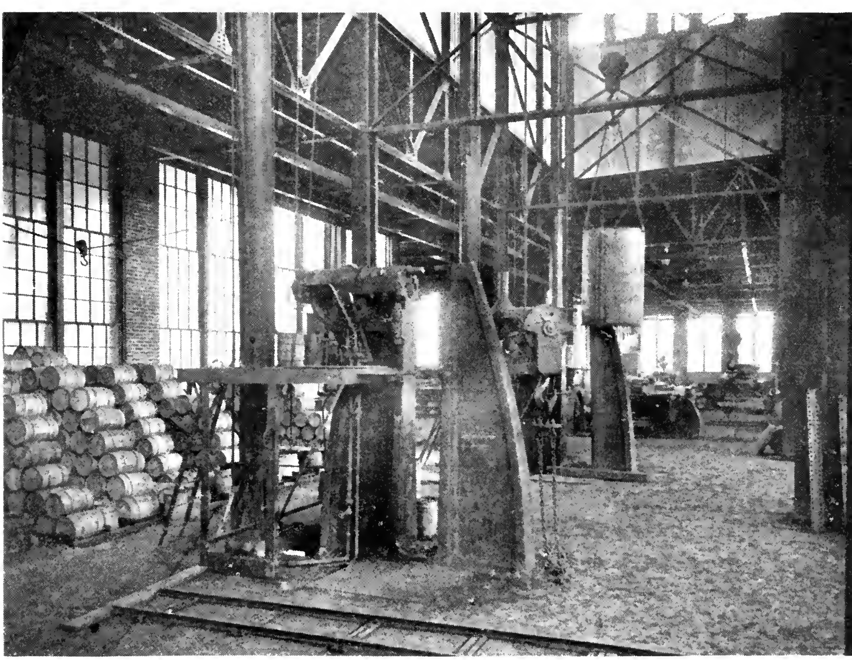
A careful study of the various illustrations shown in connection with the descriptions and explanations will, no doubt, make plain all of the points brought out and we trust, convince the reader that our claims are well founded that the Heine Boiler is economical, safe, durable, adaptable to any purpose whatsoever for which high pressure steam is required, and also that the manufacturing facilities are such that the purchaser can feel assured that he will get material and workmanship which cannot be excelled. And further, that cheap, general imitations of inferior material and workmanship are not and cannot be worth as much as the product we offer.

THE REAL AND ONLY HEINE BOILERS ARE BUILT BY THE HEINE SAFETY BOILER COMPANY ALONE.

ERECTING DEPARTMENT, HEINE SAFETY BOILER CO. SHOP, ST. LOUIS, MO.



ERECTING AND TESTING FLOOR, HEINE SAFETY BOILER CO. SHOP, ST. LOUIS, MO.



HYDRAULIC RIVETERS, HEINE SAFETY BOILER CO. SHOP, ST. LOUIS, MO.

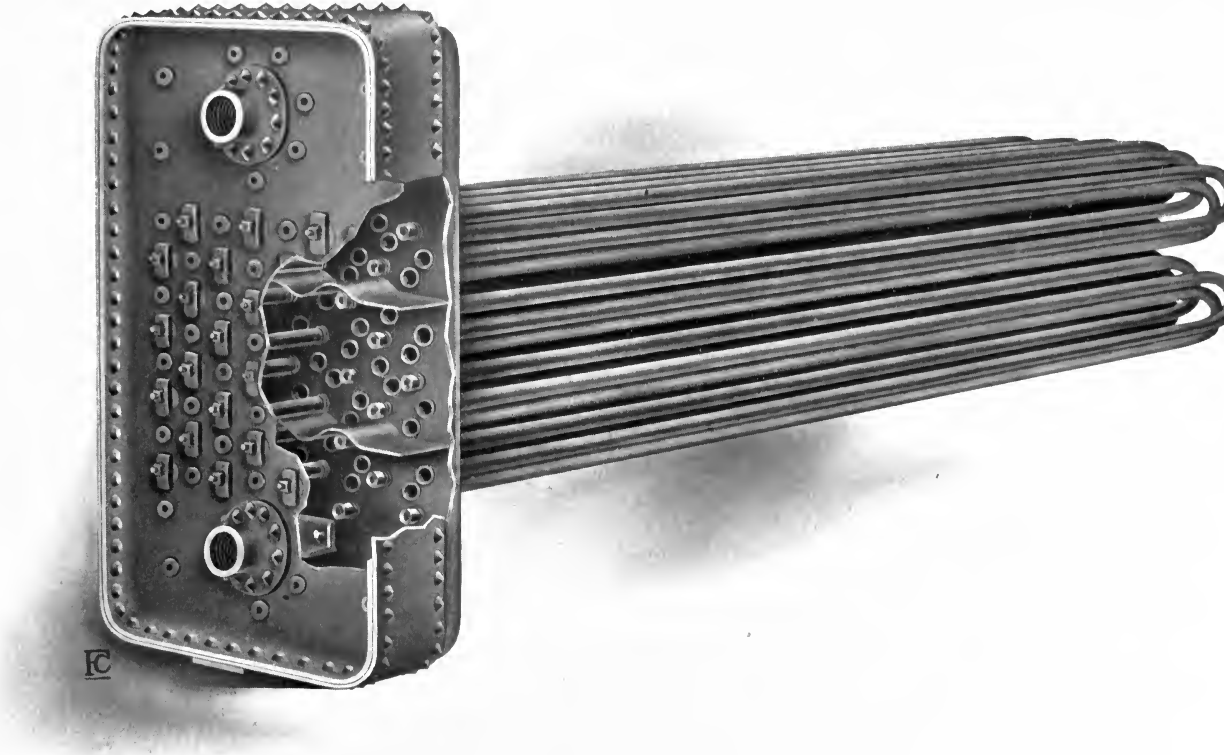


Fig. 20.

THE HEINE SUPERHEATER.

THE HEINE SUPERHEATER.

THE Heine Superheater is offered to steam users only after a thorough test of some four or five years, during which time it has been demonstrated that repairs are practically nothing and that the sizes that we have determined upon for various capacities and degrees of superheat are liberal.

We were in no haste to put the superheater on the market preferring to first perfect all details and offer to steam users only what we were sure would prove entirely satisfactory. We offer this device with full confidence that it will fulfill both our and their expectations.

CONSTRUCTION.

The Heine Superheater consists essentially of a header box of the same type of construction as the well known Heine Boiler water leg, into one side of which are inserted U tubes, made of 1½-inch seamless, drawn, mild steel tubing, expanded into holes provided for them. Opposite the tubes in the other sheet of the header box are a series of hand holes closed by inside plates, which give access to the interior of the whole apparatus.

The header box is made entirely of flange steel plate, and is so designed that it is entirely machine made. The hollow stay bolts, which hold the two sheets of the box parallel, are of the same size and material as those used in the construction of the boiler proper, and as in the case of the boiler, provide means for introducing the soot blower in order to keep the exterior surfaces of the superheater tubes clean.

The interior of this box is divided into three compartments by means of light sheet iron diaphragms, which, being nicely fitted, are sufficiently steam tight to cause the steam to pass through the tubes. (Fig. 20.)

The superheater is located at the side of the shell of the boiler toward the front and just above the last passage of the boiler gases, being supported by special castings, which rest upon the boiler tile bar and brick setting. Depending on the capacity and degree of superheat desired, the device may be single and placed only on one side; or in two parts properly connected together, one on each side of the boiler, and above the waterline. (Fig. 21.)

The whole is encased in brickwork with a fire brick roof carried by special T bars.

A small flue, built in the side walls of the setting, carries the hot gases direct from the furnace into the superheater chamber, where they

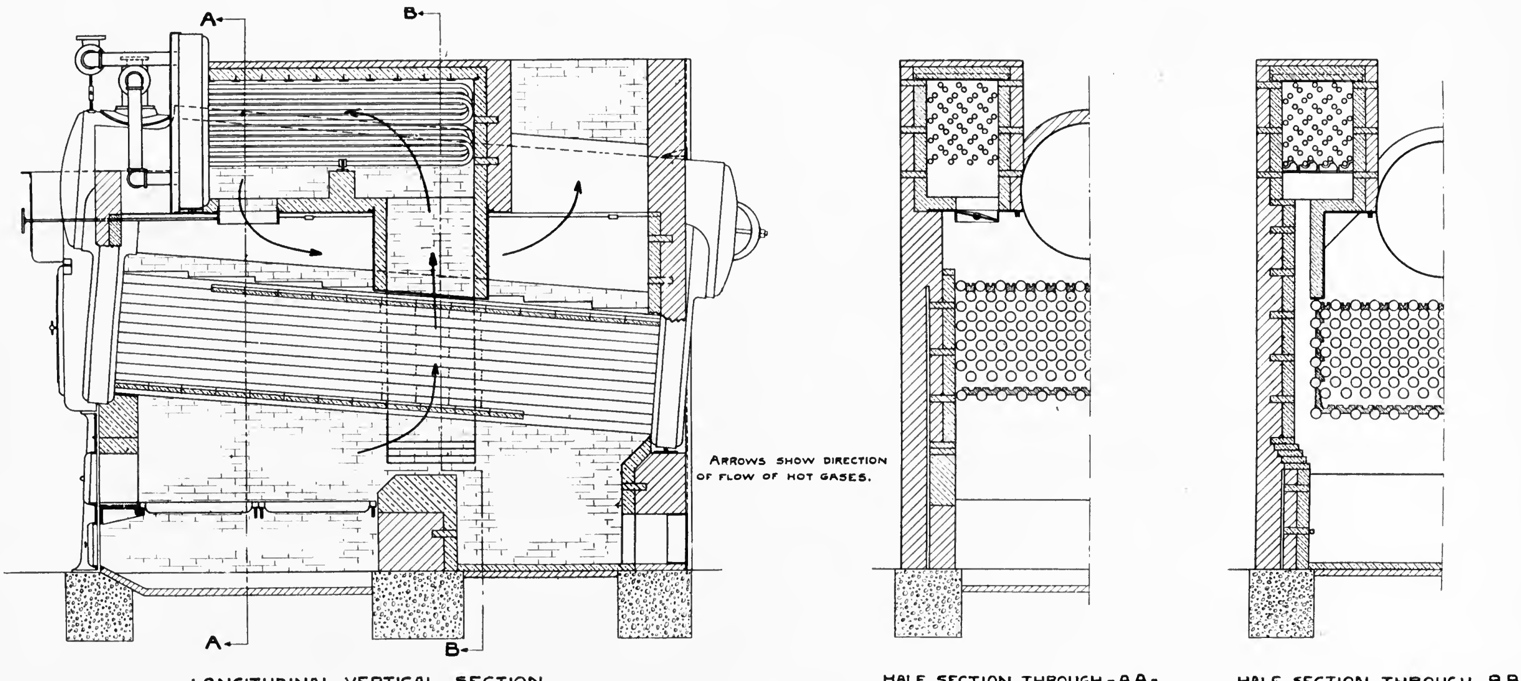


Fig. 21.

SETTING OF HEINE SUPERHEATER.

make two passes around the superheater tubes. The flow of these gases is controlled by means of a damper at the outlet. When closed the circulation is stopped, and as soon as the heat from the gases is absorbed, only saturated steam will be delivered.

By opening the damper various degrees the flow of gases can be regulated so as to give any desired degree of superheat up to the capacity of the apparatus. Since the hot gases do not come into contact with the damper until after passing through the superheater, there is no danger of overheating it.

The usual steam outlet from the boiler proper is connected into the lower opening of the superheater box, the steam passing into the tubes of the lower compartment, thence through these tubes out into the middle compartment, whence they go into the second set of tubes connected with this space and through them issuing finally into the third or top compartment, thence out through the opening there into the general piping system. The effect is to thoroughly mix up the steam so that it is of a uniform temperature. Ordinarily it is not deemed necessary to provide a by-pass so as to enable the superheater to be cut out of service entirely, although such an arrangement can easily be provided if desired.

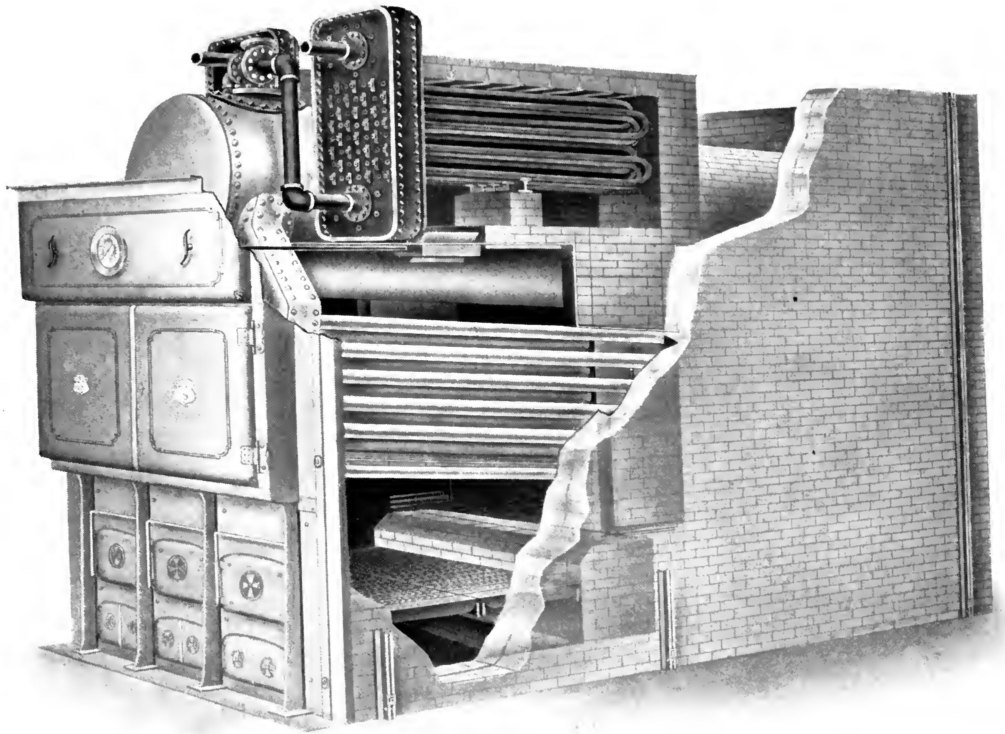
As herein before stated, a superheater demands an expenditure of fuel. A proper regard for economy therefore is a determining factor in its location; but an equally important one is ease and certainty of cleaning and inspection. If placed in the path of all gases which pass through the boiler it is difficult, or practically impossible, to design the apparatus so that it can be thoroughly inspected and swept while in operation. But when placed as in our method it is always perfectly accessible for such inspection and cleaning, thus insuring efficiency and close regulation of temperature.

It will be quite apparent that the advantage, due to our method of construction and location which permit thorough cleaning to be easily and expeditiously done, conduces to the economical use of the heat supplied to raise the temperature of the steam to the desired point.

The superheater proper is built complete and tested at the shop so that it is ready for erection and use on arrival.

Being located above and having no connection below the water line, it is never necessary to introduce any water, or, in other words, to flood the superheater, thereby absolutely preventing the accumulation of mud and scale on the interior surfaces.

The regulating damper being small and easily operated, thermostatic control of the degree of superheat is easily adaptable or the regula-

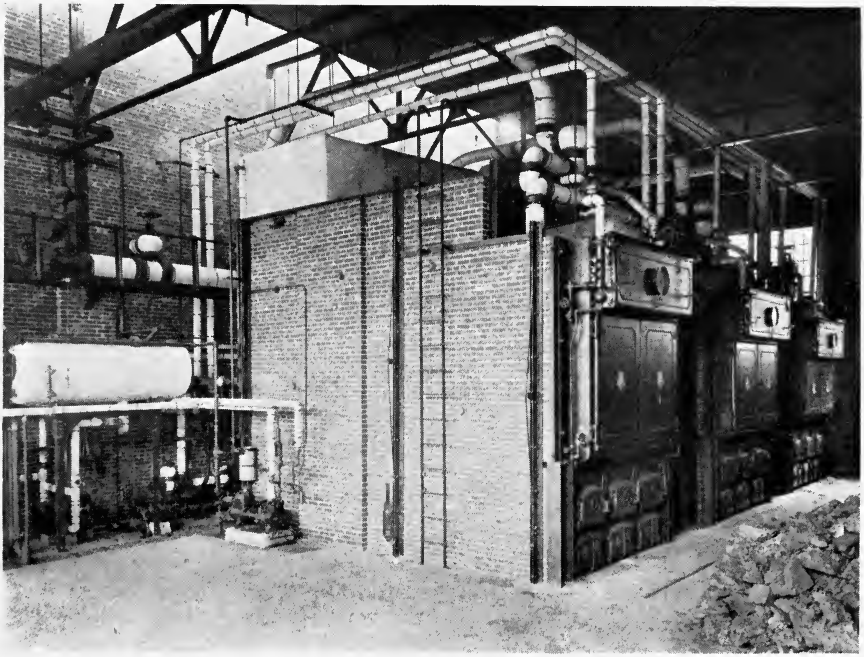


THE HEINE SUPERHEATER, SHOWING METHOD OF INSTALLATION.

tion may be attained by hand since the damper rod extends to and is operated at the front.

The exterior surfaces are perfectly smooth and hence accumulate soot to a minimum degree and are cleanable to a maximum degree, by means of the soot blower introduced through the hollow stay bolts, without in any way interfering with the operation of either boiler or superheater.

Although not shown by the illustrations the front of the apparatus is closed in by means of a frame provided with doors, giving access to the header box and preventing radiation.



BOILER ROOM OF POWER HOUSE, HEINE SAFETY BOILER CO. SHOP, ST. LOUIS, MO., EQUIPPED WITH HEINE SUPERHEATERS.

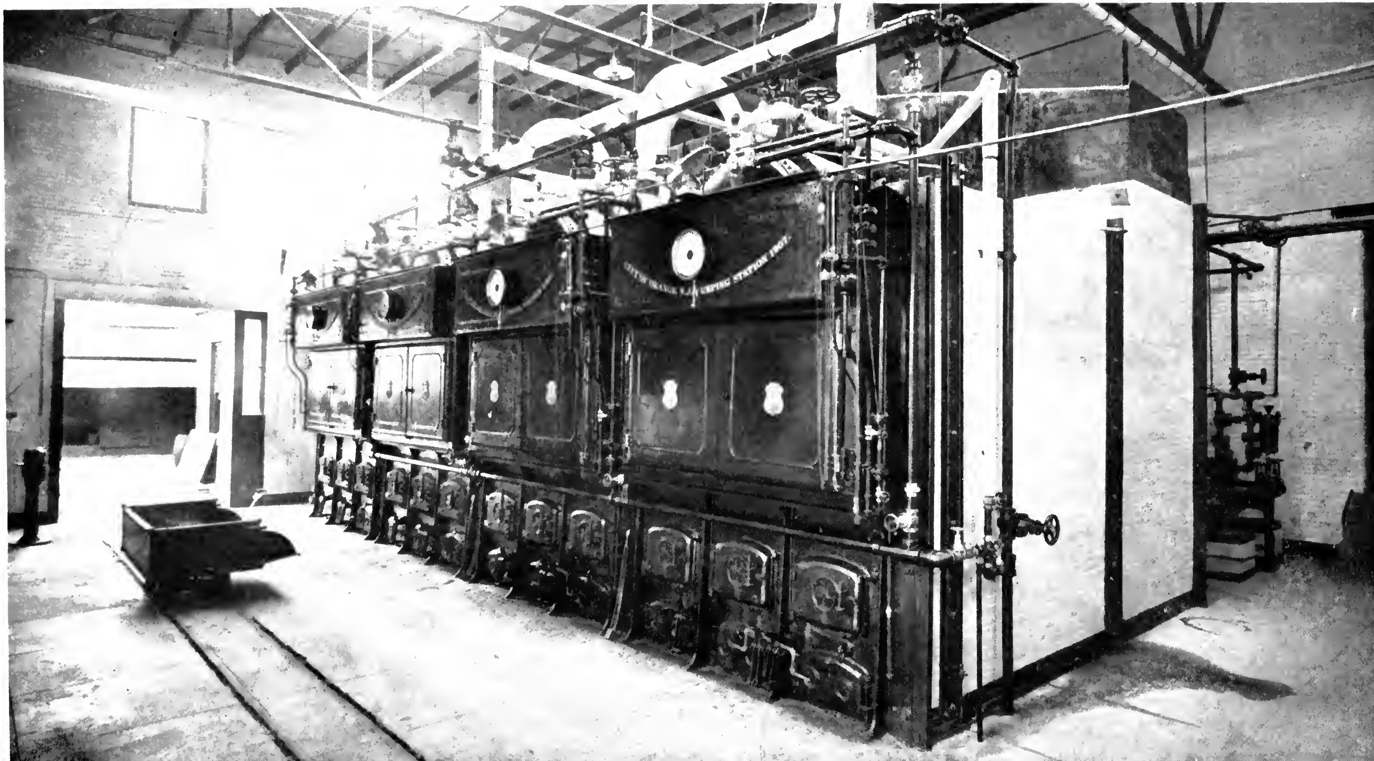
30″ DREDGE COLUMBIA, OF PORT OF PORTLAND, PORTLAND, ORE.
FITTED WITH FOUR 310 H. P. HEINE BOILERS WITH MARINE SETTINGS, J. C. B. LOCKWOOD, C. E., DESIGNER.

Table No. 60

Vulgar Fractions of a Lineal Inch in Decimal Fractions.

Advancing by Thirty-seconds.						Advancing by Odd Sixty-fourths.			
Thirty-seconds.	Fractions.	Decimals of an Inch.	Thirty-seconds.	Fractions.	Decimals of an Inch.	Sixty-fourths.	Decimals of an Inch.	Sixty-fourths.	Decimals of an Inch.
1	..	0.03125	17	..	0.53125	1	0.015625	33	0.515625
2	$\frac{1}{16}$	0.0625	18	$\frac{9}{16}$	0.5625	3	0.04687	35	0.546875
3	..	0.09375	19	..	0.59375	5	0.078125	37	0.578125
4	$\frac{1}{8}$	0.125	20	$\frac{5}{8}$	0.625	7	0.109375	39	0.609375
5	..	0.15625	21	..	0.65625	9	0.140625	41	0.640625
6	$\frac{3}{16}$	0.1875	22	$\frac{11}{16}$	0.6875	11	0.171875	43	0.671875
7	..	0.21875	23	..	0.71875	13	0.203125	45	0.703125
8	$\frac{1}{4}$	0.25	24	$\frac{3}{4}$	0.75	15	0.234375	47	0.734375
9	..	0.28125	25	..	0.78125	17	0.265625	49	0.765625
10	$\frac{5}{16}$	0.3125	26	$\frac{13}{16}$	0.8125	19	0.296875	51	0.796875
11	..	0.34375	27	..	0.84375	21	0.328125	53	0.828125
12	$\frac{3}{8}$	0.375	28	$\frac{7}{8}$	0.875	23	0.359375	55	0.859375
13	..	0.40625	29	..	0.90625	25	0.390625	57	0.890625
14	$\frac{7}{16}$	0.4375	30	$\frac{15}{16}$	0.9375	27	0.421875	59	0.921875
15	..	0.46875	31	..	0.96875	29	0.453125	61	0.953125
16	$\frac{1}{2}$	0.5	32	1	1.000	31	0.484375	63	0.984375

SHEET IRON DEPARTMENT, HEINE SAFETY BOILER CO. SHOP, ST. LOUIS, MO.



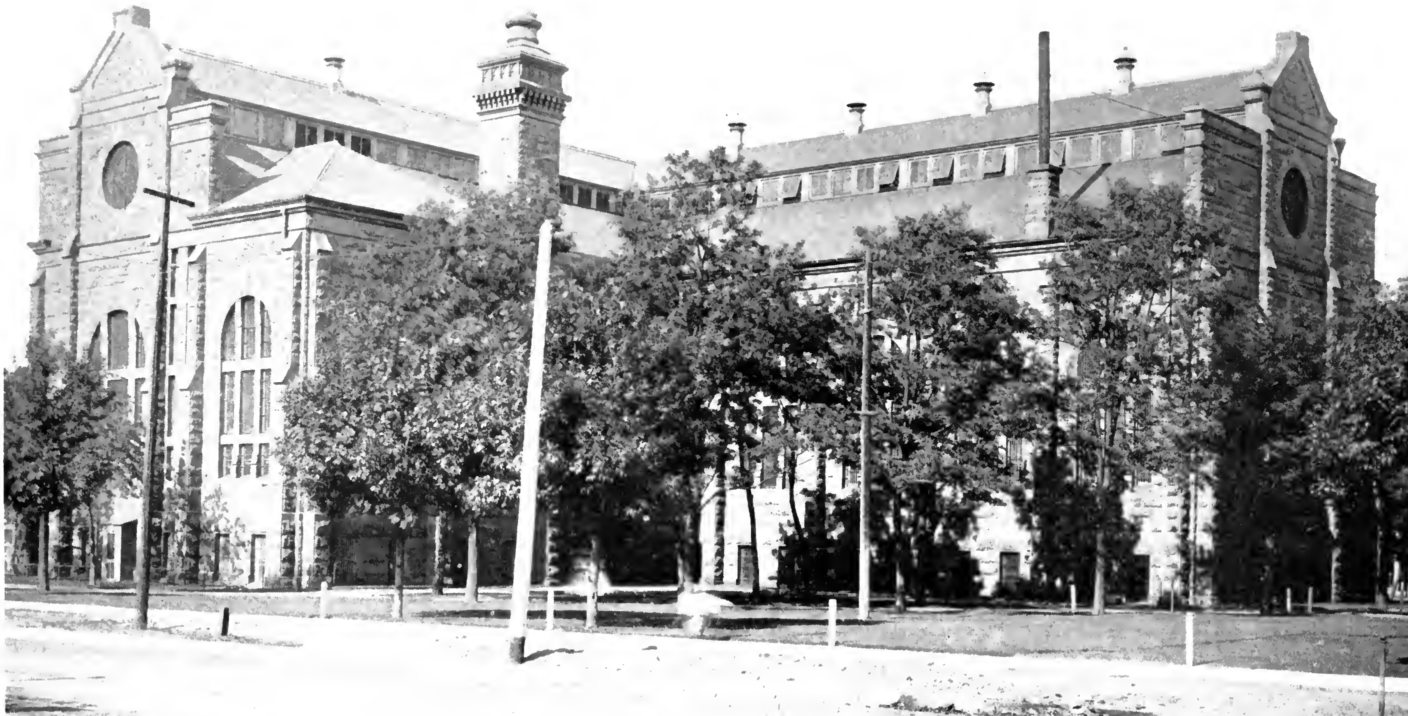
FOUR 225 H. P. HEINE BOILERS, MUNICIPAL PUMPING STATION, ORANGE, N. J.

Table No. 61

Lineal Inches in Decimal Fractions of a Lineal Foot.

Lineal Inches.	Lineal Foot.	Lineal Inches.	Lineal Foot.	Lineal Inches.	Lineal Foot.
$\frac{1}{64}$	0.001302083	$1\frac{7}{8}$	0.15625	$6\frac{1}{2}$	0.5416
$\frac{1}{32}$	0.00260416	2	0.16666	$6\frac{3}{4}$	0.5625
$\frac{1}{16}$	0.0052083	$2\frac{1}{8}$	0.177083	7	0.5833
$\frac{1}{8}$	0.010416	$2\frac{1}{4}$	0.1875	$7\frac{1}{4}$	0.60416
$\frac{3}{16}$	0.015625	$2\frac{3}{8}$	0.197916	$7\frac{1}{2}$	0.625
$\frac{1}{4}$	0.02083	$2\frac{1}{2}$	0.2083	$7\frac{3}{4}$	0.64583
$\frac{5}{16}$	0.0260416	$2\frac{5}{8}$	0.21875	8	0.66667
$\frac{3}{8}$	0.03125	$2\frac{3}{4}$	0.22916	$8\frac{1}{4}$	0.6875
$\frac{7}{16}$	0.0364583	$2\frac{7}{8}$	0.239583	$8\frac{1}{2}$	0.7083
$\frac{1}{2}$	0.0416	3	0.25	$8\frac{3}{4}$	0.72916
$\frac{9}{16}$	0.046875	$3\frac{1}{4}$	0.27083	9	0.75
$\frac{5}{8}$	0.052083	$3\frac{1}{2}$	0.2916	$9\frac{1}{4}$	0.77083
$\frac{11}{16}$	0.0572916	$3\frac{3}{4}$	0.3125	$9\frac{1}{2}$	0.7916
$\frac{3}{4}$	0.0625	4	0.33333	$9\frac{3}{4}$	0.8125
$\frac{13}{16}$	0.0677083	$4\frac{1}{4}$	0.35416	10	0.83333
$\frac{7}{8}$	0.072916	$4\frac{1}{2}$	0.375	$10\frac{1}{4}$	0.85416
$\frac{15}{16}$	0.078125	$4\frac{3}{4}$	0.39583	$10\frac{1}{2}$	0.875
1	0.0833	5	0.4166	$10\frac{3}{4}$	0.89583
$1\frac{1}{8}$	0.09375	$5\frac{1}{4}$	0.4375	11	0.9166
$1\frac{1}{4}$	0.10416	$5\frac{1}{2}$	0.4583	$11\frac{1}{4}$	0.9375
$1\frac{3}{8}$	0.114583	$5\frac{3}{4}$	0.47916	$11\frac{1}{2}$	0.9583
$1\frac{1}{2}$	0.125	6	0.5	$11\frac{3}{4}$	0.9791
$1\frac{5}{8}$	0.135416	$6\frac{1}{4}$	0.52083	12	1.0000
$1\frac{3}{4}$	0.14583	......	....	......	....

50 H. P. HEINE BOILER INSTALLED 1886, LANGLES CRACKER FACTORY, BURNED 1908, NEW ORLEANS, LA.



ARAPAHOE COUNTY JAIL, DENVER, COL., CONTAINS 300 H. P. OF HEINE BOILERS.

Table No. 62

Square Inches in Decimal Fractions of a Square Foot.

Square Inches.	Square Foot.	Square Inches.	Square Foot.	Square Inches.	Square Foot.	Square Inches.	Square Foot.
0.10	0.0006944	24.0	0.16666	65.0	0.45138	105.0	0.72916
0.15	0.0010416	25.0	0.17361	66.0	0.45833	106.0	0.73611
0.20	0.001388	26.0	0.18055	67.0	0.46527	107.0	0.74305
0.25	0.0017361	27.0	0.18750	68.0	0.47222	108.0	0.75000
0.30	0.002083	28.0	0.19444	69.0	0.47916	109.0	0.75694
0.35	0.0024305	29.0	0.20138	70.0	0.48611	110.0	0.76388
0.40	0.002777	30.0	0.20833	71.0	0.49305	111.0	0.77083
0.45	0.00311249	31.0	0.21527	72.0	0.50000	112.0	0.77777
0.50	0.003472	32.0	0.22222	73.0	0.50694	113.0	0.78472
0.55	0.0038194	33.0	0.22916	74.0	0.51388	114.0	0.79166
0.60	0.004166	34.0	0.23611	75.0	0.52083	115.0	0.79861
0.65	0.0045138	35.0	0.24305	76.0	0.52777	116.0	0.80555
0.70	0.004861	36.0	0.25000	77.0	0.53472	117.0	0.81249
0.75	0.0052083	37.0	0.25694	78.0	0.54166	118.0	0.81944
0.80	0.005555	38.0	0.26388	79.0	0.54861	119.0	0.82638
0.85	0.0059027	39.0	0.27083	80.0	0.55555	120.0	0.83333
0.90	0.006250	40.0	0.27777	81.0	0.56249	121.0	0.84027
0.95	0.0065972	41.0	0.28472	82.0	0.56944	122.0	0.84722
1.0	0.006944	42.0	0.29166	83.0	0.57638	123.0	0.85416
2.0	0.01388	43.0	0.29861	84.0	0.58333	124.0	0.86111
3.0	0.02083	44.0	0.30555	85.0	0.59027	125.0	0.86805
4.0	0.02777	45.0	0.31249	86.0	0.59722	126.0	0.87500
5.0	0.03472	46.0	0.31944	87.0	0.60416	127.0	0.88194
6.0	0.04166	47.0	0.32638	88.0	0.61111	128.0	0.88888
7.0	0.04861	48.0	0.33333	89.0	0.61805	129.0	0.89583
8.0	0.05555	49.0	0.34027	90.0	0.62500	130.0	0.90277
9.0	0.06250	50.0	0.34722	91.0	0.63194	131.0	0.90972
10.0	0.06944	51.0	0.35416	92.0	0.63888	132.0	0.91666
11.0	0.07638	52.0	0.36111	93.0	0.64583	133.0	0.92361
12.0	0.08333	53.0	0.36805	94.0	0.65277	134.0	0.93055
13.0	0.09027	54.0	0.37500	95.0	0.65972	135.0	0.93750
14.0	0.09722	55.0	0.38194	96.0	0.66666	136.0	0.94444
15.0	0.10416	56.0	0.38888	97.0	0.67361	137.0	0.95138
16.0	0.11111	57.0	0.39583	98.0	0.68055	138.0	0.95833
17.0	0.11805	58.0	0.40277	99.0	0.68750	139.0	0.96527
18.0	0.12500	59.0	0.40972	100.0	0.69444	140.0	0.97222
19.0	0.13194	60.0	0.41666	101.0	0.70138	141.0	0.97916
20.0	0.13888	61.0	0.42361	102.0	0.70833	142.0	0.98611
21.0	0.14583	62.0	0.43055	103.0	0.71527	143.0	0.99305
22.0	0.15277	63.0	0.43750	104.0	0.72222	144.0	1.0000
23.0	0.15972	64.0	0.44444				

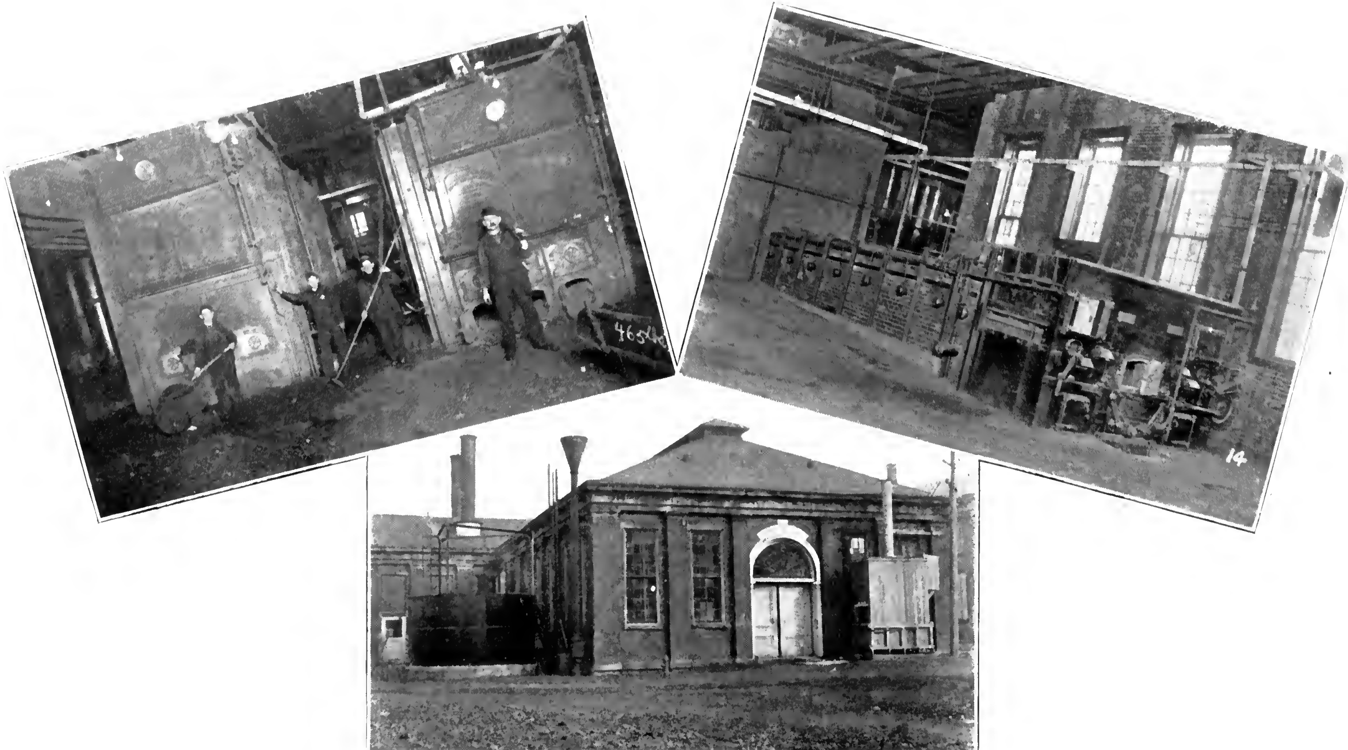
U. S. POST OFFICE, CUSTOM HOUSE AND COURT HOUSE, CLEVELAND, O., CONTAINS 750 H. P. OF HEINE BOILERS.

Table No. 63

Decimal Fractions of a Square Foot in Square Inches.

Square Foot.	Square Inches.	Square Foot.	Square Inches.	Square Foot.	Square Inches.	Square Foot.	Square Inches.
0.01	1.44	0.26	37.4	0.51	73.4	0.76	109.4
0.02	2.88	0.27	38.9	0.52	74.9	0.77	110.9
0.03	4.32	0.28	40.3	0.53	76.3	0.78	112.3
0.04	5.76	0.29	41.8	0.54	77.8	0.79	113.8
0.05	7.20	0.30	43.2	0.55	79.2	0.80	115.2
0.06	8.64	0.31	44.6	0.56	80.6	0.81	116.6
0.07	10.1	0.32	46.1	0.57	82.1	0.82	118.1
0.08	11.5	0.33	47.5	0.58	83.5	0.83	119.5
0.09	13.0	0.34	49.0	0.59	85.0	0.84	121.0
0.10	14.4	0.35	50.4	0.60	86.4	0.85	122.4
0.11	15.8	0.36	51.8	0.61	87.8	0.86	123.8
0.12	17.3	0.37	53.3	0.62	89.3	0.87	125.3
0.13	18.7	0.38	54.7	0.63	90.7	0.88	126.7
0.14	20.2	0.39	56.2	0.64	92.2	0.89	128.2
0.15	21.6	0.40	57.6	0.65	93.6	0.90	129.6
0.16	23.0	0.41	58.0	0.66	95.0	0.91	131.0
0.17	24.5	0.42	60.5	0.67	96.5	0.92	132.5
0.18	25.9	0.43	61.9	0.68	97.9	0.93	133.9
0.19	27.4	0.44	63.4	0.69	99.4	0.94	135.4
0.20	28.8	0.45	64.8	0.70	100.8	0.95	136.8
0.21	30.2	0.46	66.2	0.71	102.2	0.96	138.2
0.22	31.7	0.47	67.7	0.72	103.7	0.97	139.7
0.23	33.1	0.48	69.1	0.73	105.1	0.98	141.1
0.24	34.6	0.49	70.6	0.74	106.6	0.99	142.6
0.25	36.0	0.50	72.0	0.75	108.0	1.00	144.0

How many large modern boiler plants are now constructed with old style flue and tubular boilers—boilers in which circulation is in spite of, and not because of, their design and construction? Among the big new installations there are twenty water-tube plants now to every one of the old style. Yet many small boiler users still fail to grasp the fact that the economy of water-tube boilers is "a condition" and not "a theory."



U. S. BUREAU OF MINES, TESTING PLANT, PITTSBURGH, PA., TWO 210 H. P. HEINE BOILERS. ONE WITH JONES UNDERFEED STOKER. ONE WITH SPECIAL MURPHY FURNACE ARRANGEMENT.

Table No. 64

Metric-English Conversion Tables.

Long Measure.

1 Meter = 39.37 Inches.

No.	64th of an Inch to Millimeters.	Millimeters to 64ths of an Inch.	Inches to Centimeters.	Centimeters to Inches.
1	0.3969	2.5197	2.54	0.3937
2	0.7938	5.0394	5.08	0.7874
3	1.1906	7.5590	7.62	1.1811
4	1.5875	10.0787	10.16	1.5748
5	1.9844	12.5984	12.70	1.9685
6	2.3813	15.1181	15.24	2.3622
7	2.7781	17.6378	17.78	2.7559
8	3.1750	20.1574	20.32	3.1496
9	3.5719	22.6771	22.86	3.5433
	Meters to Feet.	**Feet to Meters.**	**Kilometers to Miles.**	**Miles to Kilometers.**
1	3.2808	0.3048	0.62137	1.60935
2	6.5617	0.6096	1.24274	3.21869
3	9.8425	0.9144	1.86411	4.82804
4	13.1233	1.2192	2.48548	6.43739
5	16.4042	1.5240	3.10685	8.04674
6	19.6850	1.8288	3.72822	9.65608
7	22.9658	2.1336	4.34959	11.26543
8	26.2467	2.4384	4.97096	12.87478
9	29.5275	2.7432	5.59233	14.48412

Square Measure.

No.	Sq. Inches to Sq. Centimeters.	Sq. Centimeters to Sq. Inches.	Sq. Feet to Sq. Meters.	Sq. Meters to Sq. Feet.	Sq. Yards to Sq. Meters.	Sq. Meters to Sq. Yards.
1	6.4516	0.155	0.0929	10.7639	0.8361	1.196
2	12.9032	0.310	0.1858	21.5278	1.6722	2.392
3	19.3548	0.465	0.2787	32.2917	2.5084	3.588
4	25.8064	0.620	0.3716	43.0556	3.3445	4.784
5	32.2581	0.775	0.4645	53.8194	4.1806	5.980
6	38.7097	0.930	0.5574	64.5833	5.0167	7.176
7	45.1613	1.085	0.6503	75.3472	5.8528	8.372
8	51.6129	1.240	0.7432	86.1111	6.6890	9.568
9	58.0645	1.395	0.8361	96.8750	7.5251	10.764
	Acres to Hectares.	**Hectares to Acres.**	**Sq. Miles to Sq. Kilometers.**	**Sq. Kilometers to Sq. Miles.**	**Sq. Miles to Hectares.**	**Hectares to Sq. Miles.**
1	0.4047	2.471	2.59	0.3861	259.00	0.00386
2	0.8094	4.942	5.18	0.7722	518.00	0.00772
3	1.2141	7.413	7.77	1.1583	777.01	0.01158
4	1.6188	9.884	10.36	1.5444	1036.01	0.01544
5	2.0235	12.355	12.95	1.9305	1295.02	0.01930
6	2.4282	14.826	15.54	2.3166	1554.02	0.02317
7	2.8329	17.297	18.13	2.7027	1813.03	0.02703
8	3.2376	19.768	20.72	3.0887	2072.03	0.03089
9	3.6422	22.239	23.31	3.4748	2331.04	0.03475

Table No. 65

Metric-English Conversion Tables.

Weights.

1 Kilogram = 2.2406 Pounds.

No.	Kilograms to Ounces Troy.	Troy Ounces to Kilograms.	Grains to Milligrams.	Grams to Grains.	Gross Tons to Metric Tons.	Metric Tons to Gross Tons.
1	32.1507	31.1035	64.8004	15.432	1.0162	0.9842
2	64.3015	62.2070	129.6008	30.864	2.0321	1.9684
3	96.4522	93.3104	194.4012	46.296	3.0482	2.9526
4	128.6030	124.4139	259.2017	61.728	4.0642	3.9368
5	160.7537	155.5174	324.0021	77.160	5.0803	4.9210
6	192.9045	186.6209	388.8025	92.592	6.0963	5.9052
7	225.0552	217.7244	453.6029	108.024	7.1124	6.8894
8	257.2059	248.8278	518.4033	123.456	8.1285	7.8736
9	289.3567	279.9313	583.2037	138.888	9.1445	8.8578

No.	Avoir. Ounces to Grams.	Grams to Ounces Avoir.	Avoir. Pounds to Kilograms.	Kilograms to Pounds Avoir.	Net Tons to Metric Tons.	Metric Tons to Net Tons.
1	28.3495	35.274	0.4536	2.2046	0.9072	1.1023
2	56.6990	70.548	0.9072	4.4092	1.8144	2.2046
3	85.0485	105.822	1.3608	6.6138	2.7216	3.3069
4	113.3980	141.096	1.8144	8.8184	3.6288	4.4092
5	141.7475	176.370	2.2680	11.0230	4.5360	5.5115
6	170.0970	211.644	2.7216	13.2276	5.4432	6.6138
7	198.4464	246.918	3.1752	15.4322	6.3504	7.7161
8	226.7959	282.192	3.6288	17.6368	7.2576	8.8184
9	255.1454	317.466	4.0824	19.8414	8.1647	9.9207

Liquid and Dry Measure.

1 Liter = { 1.0567 Quarts—Liquid Measure. / 0.908 Quarts—Dry Measure.

No.	Liters to Quarts.		Quarts to Liters.		Liters to Gallons Liquid.	Gallons to Liters Liquid.
	Liquid.	Dry.	Liquid.	Dry.		
1	1.0567	0.908	0.9436	1.1013	0.2642	3.7854
2	2.1134	1.816	1.8927	2.2026	0.5284	7.5707
3	3.1701	2.724	2.8390	3.3040	0.7925	11.3561
4	4.2268	3.632	3.7854	4.4053	1.0567	15.1415
5	5.2835	4.540	4.7317	5.5066	1.3209	18.9268
6	6.3402	5.448	5.6781	6.6079	1.5851	22.7122
7	7.3969	6.356	6.6244	7.7093	1.8492	26.4976
8	8.4536	7.264	7.5707	8.8106	2.1134	30.2830
9	9.5103	8.172	8.5171	9.9119	2.3776	34.0683

No.	Cubic Meters to Gallons-Liquid.	Gallons to Cubic Meters Liquid.	Hectoliters to Bushels-Dry.	Bushels to Hectoliters Dry.
1	264.17	0.0038	2.8375	0.3524
2	528.34	0.0076	5.6750	0.7048
3	792.51	0.0114	8.5125	1.0573
4	1056.68	0.0151	11.3500	1.4097
5	1320.85	0.0189	14.1875	1.7621
6	1585.02	0.0227	17.0250	2.1145
7	1849.19	0.0265	19.8625	2.4670
8	2113.36	0.0303	22.7000	2.8194
9	2377.53	0.0341	25.5375	3.1718

Table No. 66.

Metric-English Conversion Tables.

Cubic—Horse Power—Ton Measures

No.	Cubic Centimeters to Cubic Inches.	Cubic Inches to Cubic Centimeters.	Cubic Meters to Cubic Feet.	Cubic Feet to Cubic Meters.	Cubic Meters to Cubic Yards.	Cubic Yards to Cubic Meters.
1	0.061	16.3934	35.316	0.0283	1.308	0.7645
2	0.122	32.7869	70.632	0.0566	2.616	1.5291
3	0.183	49.1803	105.948	0.0849	3.924	2.2936
4	0.244	65.5738	141.264	0.1133	5.232	2.0581
5	0.305	81.9672	176.580	0.1416	6.540	3.8226
6	0.366	98.3607	211.896	0.1699	7.848	4.5872
7	0.427	114.7541	247.212	0.1982	9.156	5.3517
8	0.488	131.1475	282.528	0.2265	10.464	6.1162
9	0.549	147.5410	317.844	0.2548	11.772	6.8807
No.	Horse Power Metric to U. S.	Horse Power U. S. to Metric.	Foot Pounds to Kilogram Meters.	Kilogram Meters to Foot Pounds.	Gross Tons per Sq. Foot to Metric Tons per Sq. Meter.	Metric Tons per Sq. Meter to Gross Tons per Sq. Foot.
1	0.986	1.014	0.1383	7.2329	10.937	0.091
2	1.973	2.028	0.2765	14.4659	21.873	0.183
3	2.959	3.042	0.4148	21.6988	32.810	0.274
4	3.945	4.056	0.5530	28.9317	43.747	0.366
5	4.932	5.069	0.6913	36.1646	54.684	0.457
6	5.918	6.083	0.8295	43.3976	65.620	0.549
7	6.904	7.097	0.9678	50.6305	76.557	0.640
8	7.890	8.111	1.1061	57.8634	87.494	0.731
9	8.877	9.125	1.2443	65.0963	98.431	0.823

Miscellaneous.

No.	Kilo. per Meter to Pounds per Foot.	Pounds per Foot to Kilo. per Meter.	Kilo. per Sq. Meter to Pounds per Sq. Foot.	Pounds per Sq. Foot to Kilo. per Sq. Meter.
1	0.6720	1.4882	0.2048	4.8825
2	1.3439	2.9764	0.4096	9.7649
3	2.0159	4.4645	0.6144	14.6474
4	2.6879	5.9527	0.8193	19.5299
5	3.3598	7.4409	1.0241	24.4123
6	4.0318	8.9291	1.2289	29.2948
7	4.7037	10.4172	1.4337	34.1773
8	5.3757	11.9054	1.6385	39.0597
9	6.0477	13.3936	1.8433	43.9422
No.	Kilo. per Cubic Meter to Pounds per Cubic Foot.	Pounds per Cubie Foot to Kilo. per Cubic Meter.	Kilo. per Sq. Centimeter to Pounds per Sq. Inch.	Pounds per Sq. Inch to Kilo. per Sq. Centimeter.
1	0.0624	16.0192	14.2232	0.0703
2	0.1248	32.0385	28.4465	0.1406
3	C.1873	48.0577	42.6697	0.2109
4	0.2497	64.0769	56.8929	0.2812
5	0.3121	80.0962	71.1161	0.3515
6	0.3745	96.1154	85.3394	0.4218
7	0.4370	112.1346	99.5626	0.4922
8	0.4994	128.1539	113.7858	0.5625
9	0.5618	144.1731	128.0090	0.6328

TWO 500 H. P. HEINE BOILERS, ST. CHARLES HOTEL,
NEW ORLEANS, BURNING FUEL OIL.

Table No. 67.

Wrought Iron, Steel, Copper and Brass Plates.

Birmingham Gauge.

No. of Gauge.	Thickness, Inches.	Weight Per Square Foot, Lbs.			
		Iron.	Steel.	Copper.	Brass.
0000	0.454 or 7/16 full......	18.2167	18.4596	20.5662	19.4312
000	0.425	17.0531	17.2805	19.2525	18.1900
00	0.38 or 3/8 full.......	15.2475	15.4508	17.2140	16.2640
0	0.34 or 1/3 full	13.6425	13.8244	15.4020	14.5520
1	0.3	12.0375	12.1980	13.5900	12.8400
2	0.284	11.3955	11.5474	12.8652	12.1552
3	0.259 or 1/4 full.......	10.9324	10.5309	11.7327	11.0852
4	0.238	9.5497	9.6771	10.7814	10.1864
5	0.22	8.8275	8.9452	9.9660	9.4160
6	0.203 or 1/5 full......	8.1454	8.2540	9.1959	8.6884
7	0.18 or 3/16 light.....	7.2225	7.3188	8.1540	7.7040
8	0.165 or 1/6 light.....	6.6206	6.7089	7.4745	7.0620
9	0.148 or 1/7 full.......	5.9385	6.0177	6.7044	6.3344
10	0.134	5.3767	5.4484	6.0702	5.7352
11	0.12 or 1/8 light.....	4.8150	4.8792	5.4360	5.1360
12	0.109	4.3736	4.4319	4.9377	4.6652
13	0.095 or 1/10 light	3.8119	3.8627	4.3035	4.0660
14	0.083	3.3304	3.3748	3.7599	3.5524
15	0.072	2.8890	2.9275	3.2616	3.0816
16	0.065	2.6081	2.6429	2.9445	2.7820
17	0.058	2.3272	2.3583	2.6274	2.4824
18	0.049 or 1/20 light....	1.9661	1.9923	2.2197	2.0972
19	0.042	1.6852	1.7077	1.9026	1.7976
20	0.035	1.4044	1.4231	1.5855	1.4980
21	0.032	1.2840	1.3011	1.4496	1.3696
22	0.028	1.1235	1.1385	1.2684	1.1984
23	0.025 or 1/40.........	1.0031	1.0165	1.1325	1.0700
24	0.022	0.8827	0.8945	0.9966	0.9416
25	0.02 or 1/50.........	0.8025	0.8132	0.9060	0.8560
26	0.018	0.7222	0.7319	0.8154	0.7704
27	0.016	0.6420	0.6506	0.7248	0.6848
28	0.014	0.5617	0.5692	0.6342	0.5992
29	0.013	0.5216	0.5286	0.5889	0.5564
30	0.012	0.4815	0.4879	0.5436	0.5136
31	0.001 or 1/100.........	0.4012	0.4066	0.4530	0.4280
32	0.009	0.3611	0.3659	0.4077	0.3852
33	0.008	0.3210	0.3253	0.3624	0.3424
34	0.007	0.2809	0.2846	0.3171	0.2996
35	0.005 or 1/200.........	0.2006	0.2033	0.2265	0.2140
36	0.004 or 1/250.........	0.1605	0.1626	0.1812	0.1712
	1.00 inch thick.......	41.5696	42.1236	46.9308	44.3408

"Boiler Room Tactics" as the name implies, is a guide to the proper manipulation of boilers. It is a little booklet issued by the Heine Safety Boiler Co. with special reference to the Heine Boiler, but there is much that is applicable to any boiler.

CITY AND COUNTY BUILDING, SALT LAKE CITY, UTAH, CONTAINS 675 H. P. OF HEINE BOILERS.

Table No. 68

Weight of Square and Round Iron.

Per Foot of Length.

Side or Diam.	Weight, Square.	Weight, Round.	Side or Diam.	Weight, Square.	Weight, Round.	Side or Diam.	Weight, Square.	Weight, Round.
1/16	.013	.01	2	13.52	10.616	5	84.48	66.35
1/8	.053	.041	1/8	15.263	11.988	1/4	93.168	73.172
3/16	.118	.093	1/4	17.112	13.44	1/2	102.24	80.304
1/4	.211	.165	3/8	19.066	14.975	3/4	111.756	87.776
3/8	.475	.373	1/2	21.12	16.588			
1/2	.845	.663	5/8	23.292	18.293	6	121.664	95.552
5/8	1.32	1.043	3/4	25.56	20.076	1/4	132.04	103.704
3/4	1.901	1.493	7/8	27.939	21.944	1/2	142.816	112.16
7/8	2.588	2.032				3/4	154.012	120.96
			3	30.416	23.888			
1	3.38	2.654	1/4	35.704	28.04	7	165.632	130.048
1/8	4.278	3.359	1/2	41.408	32.515	1/4	177.672	139.544
1/4	5.28	4.147	3/4	47.534	37.332	1/2	190.136	149.328
3/8	6.39	5.019		54.084	42.464	3/4	203.024	159.456
1/2	7.604	5.972	4					
5/8	8.926	7.01	1/4	61.055	47.952	8	216.336	169.856
3/4	10.352	8.128	1/2	68.448	53.76			
7/8	11.883	9.333	3/4	76.264	59.9	9	273.792	215.04

HECKER, JONES, JEWELL MILLING CO., NEW YORK, N. Y.
CONTAINS 2000 H. P. OF HEINE BOILERS.

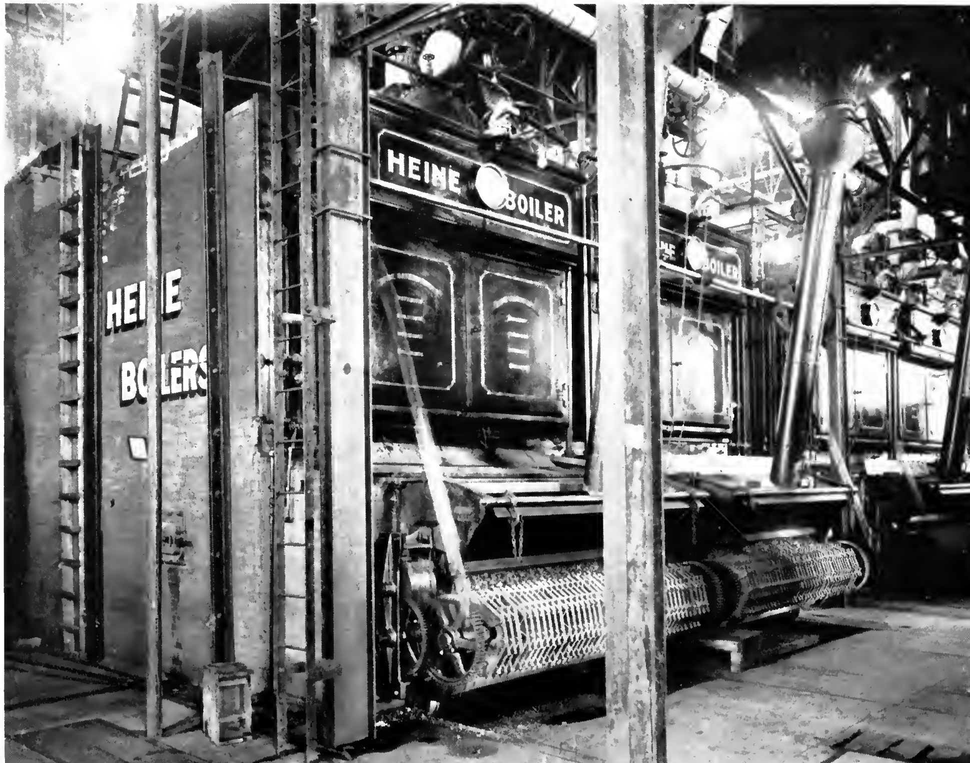
HOTEL ST. REGIS, NEW YORK, N. Y.,
CONTAINS 1450 H. P. OF HEINE BOILERS.

Table No. 69

Standard Boiler Tubes.

Table of Standard Dimensions.

Diameter.		Standard Thickness.		Transverse Areas.		Area of Surface per Foot of Tube.		Nominal Weight per Foot—Lbs.				
External.	Internal.	Nearest B. W. G.	Inches.	External.	Internal.	External.	Internal.	Standard Thickness.	One Extra Wire Gauge.	Two Extra Wire Gauges.	Three Extra Wire Gauges.	Four Extra Wire Gauges.
Inches.	Inches.	No.		Sq. Inches.	Sq. Inches.	Sq. Foot.	Sq. Foot.					
1	0.810	13	.095	0.785	0.515	.262	.212	0.90	1.04	1.13	1.24	1.35
1¼	1.060	13	.095	1.227	0.882	.327	.277	1.15	1.33	1.45	1.60	1.74
1½	1.310	13	.095	1.767	1.348	.392	.343	1.40	1.62	1.77	1.96	2.14
1¾	1.560	13	.095	2.405	1.911	.458	.408	1.66	1.91	2.09	2.31	2.53
2	1.810	13	.095	3.142	2.573	.523	.474	1.91	2.20	2.41	2.67	2.93
2¼	2.060	13	.095	3.976	3.333	.589	.539	2.16	2.49	2.73	3.03	3.32
2½	2.282	12	.109	4.909	4.090	.654	.597	2.75	3.05	3.39	3.72	4.12
2¾	2.532	12	.109	5.940	5.035	.720	.663	3.04	3.37	3.74	4.11	4.56
3	2.782	12	.109	7.069	6.079	.785	.728	3.33	3.69	4.10	4.51	5.00
3¼	3.010	11	.120	8.296	7.116	.851	.788	3.96	4.46	4.90	5.44	5.90
3½	3.260	11	.120	9.621	8.347	.916	.853	4.28	4.82	5.30	5.88	6.38
3¾	3.510	11	.120	11.045	9.676	.982	.919	4.60	5.18	5.69	6.32	6.86
4	3.732	10	.134	12.566	10.939	1.047	.977	5.47	6.09	6.76	7.34	8.23
4½	4.232	10	.134	15.904	14.066	1.178	1.108	6.17	6.88	7.64	8.31	9.32
5	4.704	9	.148	19.635	17.379	1.309	1.231	7.58	8.52	9.27	10.40	11.23
6	5.670	8	.165	28.274	25.250	1.571	1.484	10.16	11.19	12.57	13.58	14.65



FOUR OF THE EIGHT 400 H. P. HEINE BOILERS, LOUISIANA PURCHASE EXPOSITION, ST. LOUIS, MO., EQUIPPED WITH GREEN CHAIN GRATE STOKERS.

Table No. 70

Table of Standard Dimensions.

Standard Steam, Gas and Water Pipe.

Size.	Diameter. Nominal External.	Diameter. Approx. Internal.	Nominal Thickness.	Internal Transverse Area.	Nominal Weight Per Foot.	Number of Threads Per Inch of Screw,
Inches.	Inches.	Inches.	Inches.	Sq. Inches	Pounds.	
1/8	.405	.27	.068	.0568	0.24	27
1/4	.540	.364	.088	.1041	0.42	18
3/8	.675	.494	.091	.1909	0.56	18
1/2	.840	.623	.109	.3039	0.84	14
3/4	1.05	.824	.113	.5333	1.12	14
1	1.315	1.048	.134	.8609	1.67	11½
1¼	1.66	1.380	.140	1.496	2.24	11½
1½	1.90	1.611	.145	2.038	2.68	11½
2	2.375	2.067	.154	3.356	3.61	11½
2½	2.875	2.468	.204	4.780	5.74	8
3	3.500	3.067	.217	7.388	7.54	8
3½	4.000	3.548	.226	9.887	9.00	8
4	4.500	4.026	.237	12.730	10.66	8
4½	5.000	4.508	.246	15.961	12.49	8
5	5.563	5.045	.259	19.985	14.50	8
6	6.625	6.065	.280	28.886	18.76	8
7	7.625	7.023	.301	38.743	23.27	8
8	8.625	8.073	.276	50.931	25.00	8
8	8.625	7.982	.322	50.021	28.18	8
9	9.625	8.937	.344	62.722	33.70	8
10	10.75	10.194	.278	81.615	32.00	8
10	10.75	10.138	.306	80.720	35.00	8
10	10.75	10.019	.366	78.822	40.00	8
11	11.75	11.000	.375	95.034	45.00	8
12	12.75	12.094	.328	114.875	45.00	8
12	12.75	12.000	.375	113.098	49.00	8

Extra Strong Steam, Gas and Water Pipe.

Size.	Diameter. Nominal External.	Diameter. Approx. Internal.	Nominal Thickness.	Internal Transverse Area.	Nominal Weight Per Foot.	Number of Threads Per Inch of Screw.
Inches.	Inches.	Inches.	Inches.	Sq. Inches.	Pounds.	
1/8	.405	.205	.100	.033	.29	27
1/4	.540	.294	.123	.068	.54	18
3/8	.675	.421	.127	.139	.74	18
1/2	.840	.542	.149	.231	1.09	14
3/4	1.05	.736	.157	.425	1.39	14
1	1.315	.951	.182	.710	2.17	11½
1¼	1.66	1.272	.194	1.271	3.00	11½
1½	1.90	1.494	.203	1.753	3.63	11½
2	2.375	1.933	.221	2.935	5.02	11½
2½	2.875	2.315	.280	4.209	7.67	8
3	3.500	2.892	.304	6.569	10.25	8
3½	4.000	3.358	.321	8.856	12.47	8
4	4.500	3.818	.341	11.449	14.97	8
4½	5.000	4.280	.360	14.387	18.22	8
5	5.563	4.813	.375	18.193	20.54	8
6	6.625	5.750	.437	25.976	28.58	8
7	7.625	6.625	.500	34.472	37.67	8
8	8.625	7.625	.500	45.664	43.00	8
9	9.625	8.625	.500	58.426	48.73	8
10	10.75	9.75	.500	74.662	54.74	8
11	11.75	10.75	.500	90.763	60.08	8
12	12.75	11.75	.500	108.430	65.42	8

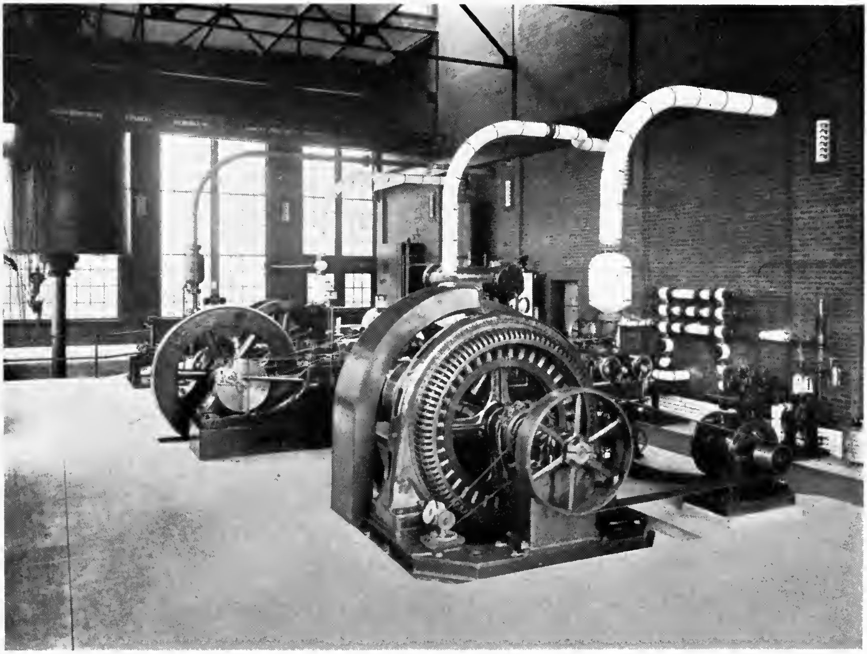
6650 H. P. OF HEINE BOILERS, E. ST. LOUIS AND SUBURBAN RY. CO., EQUIPPED WITH GREEN CHAIN GRATES.

Table No. 71.

Double Extra Strong Steam, Gas and Water Pipe.

Table of Standard Dimensions.

Size.	Diameter. Nominal External.	Diameter. Approx. Internal.	Nominal Thickness.	Internal Transverse Area.	Nominal Weight Per Foot.	Number of Threads Per Inch of Screw.
Inches.	Inches.	Inches.	Inches.	Sq. Inches.	Pounds.	
½	.84	.244	.298	.047	1.70	14
¾	1.05	.422	.314	.140	2.44	14
1	1.315	.587	.364	.271	3.65	11½
1¼	1.66	.885	.388	.615	5.20	11½
1½	1.90	1.088	.406	.930	6.40	11½
2	2.375	1.491	.442	1.744	9.02	11½
2½	2.875	1.755	.560	2.419	13.68	8
3	3.50	2.284	.608	4.097	18.56	8
3½	4.00	2.716	.642	5.794	22.75	8
4	4.50	3.136	.682	7.724	27.48	8
4½	5.00	3.564	.718	9.976	32.53	8
5	5.563	4.063	.75	12.965	38.12	8
6	6.625	4.875	.875	18.665	53.11	8
7	7.625	5.875	.875	27.109	62.38	8
8	8.625	6.875	.875	37.122	71.62	8



ENGINE ROOM OF POWER HOUSE, HEINE SAFETY BOILER CO. SHOP. ST. LOUIS, MO.

Table No. 72

Diameters, Circumferences and Areas of Circles.

Advancing by 8ths.

Diam.	Circum.	Area	Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.
0	0.000	0.0000	8	25.13	50.265	16	50.27	201.06	24	75.40	452.39	32	100.531	804.25	40	125.664	1256.64
⅛	0.393	0.0123	⅛	25.53	51.849	⅛	50.66	204.22	⅛	75.79	457.11	⅛	100.924	810.54	⅛	126.056	1264.51
¼	0.785	0.0491	¼	25.92	53.456	¼	51.05	207.39	¼	76.18	461.86	¼	101.316	816.86	¼	126.449	1272.40
⅜	1.178	0.1104	⅜	26.31	55.088	⅜	51.44	210.60	⅜	76.58	466.64	⅜	101.709	823.21	⅜	126.842	1280.31
½	1.571	0.1963	½	26.70	56.745	½	51.84	213.82	½	76.97	471.44	½	102.102	829.58	½	127.235	1288.25
⅝	1.963	0.3068	⅝	27.10	58.426	⅝	52.23	217.08	⅝	77.36	476.26	⅝	102.494	835.97	⅝	127.627	1296.22
¾	2.356	0.4418	¾	27.49	60.132	¾	52.62	220.35	¾	77.75	481.11	¾	102.887	842.93	¾	128.020	1304.21
⅞	2.749	0.6013	⅞	27.88	61.862	⅞	53.01	223.65	⅞	78.15	485.98	⅞	103.280	848.83	⅞	128.413	1312.22
1	3.142	0.7854	9	28.27	63.617	17	53.41	226.98	25	78.54	490.87	33	103.673	855.30	41	128.805	1320.26
⅛	3.534	0.9940	⅛	28.67	65.397	⅛	53.80	230.33	⅛	78.93	495.79	⅛	104.065	861.79	⅛	129.198	1328.32
¼	3.927	1.2272	¼	29.06	67.201	¼	54.19	233.71	¼	79.33	500.74	¼	104.458	868.31	¼	129.591	1336.41
⅜	4.320	1.4849	⅜	29.45	69.029	⅜	54.59	237.10	⅜	79.72	505.71	⅜	104.851	874.85	⅜	129.983	1344.52
½	4.712	1.7671	½	29.85	70.882	½	54.98	240.53	½	80.11	510.71	½	105.243	881.41	½	130.376	1352.66
⅝	5.105	2.0739	⅝	30.24	72.760	⅝	55.37	243.98	⅝	80.50	515.72	⅝	105.636	888.00	⅝	130.769	1360.82
¾	5.498	2.4053	¾	30.63	74.662	¾	55.76	247.45	¾	80.90	520.77	¾	106.029	894.62	¾	131.161	1369.00
⅞	5.890	2.7612	⅞	31.02	76.589	⅞	56.16	250.95	⅞	81.29	525.84	⅞	106.421	901.26	⅞	131.554	1377.21
2	6.283	3.1416	10	31.42	78.540	18	56.55	254,47	26	81.68	530.93	34	106.814	907.92	42	131.947	1385.45
⅛	6.676	3.5466	⅛	31.81	80.516	⅛	56.94	258.02	⅛	82.07	536.05	⅛	107.207	914.61	⅛	132.340	1393.70
¼	7.069	3.9761	¼	32.20	82.516	¼	57.33	261.59	¼	82.47	541.19	¼	107.600	921.32	¼	132.732	1401.99
⅜	7.461	4.4301	⅜	32.59	84.541	⅜	57.73	265.18	⅜	82.86	546.35	⅜	107.992	928.06	⅜	133.125	1410.30
½	7.854	4.9087	½	32.99	86.590	½	58.12	268.80	½	83.25	551.55	½	108.385	934.82	½	133.518	1418.65
⅝	8.247	5.4119	⅝	33.38	88.664	⅝	58.51	272.45	⅝	83.64	556.76	⅝	108.778	941.61	⅝	133.910	1426.96
¾	8.639	5.9396	¾	33.77	90.763	¾	58.90	276.12	¾	84.04	562.00	¾	109.170	948.42	¾	134.303	1435.37
⅞	9.032	6.4918	⅞	34.16	92.886	⅞	59.30	279.81	⅞	84.43	567.27	⅞	109.563	955.25	⅞	134.696	1448.77
3	9.425	7.0686	11	34.56	95.033	19	59.69	283.53	27	84.82	572.56	35	109.956	962.11	43	135.088	1452.20
⅛	9.817	7.6699	⅛	34.95	97.205	⅛	60.08	287.27	⅛	85.22	577.87	⅛	110.348	969.00	⅛	135.481	1460.66
¼	10.210	8.2958	¼	35.34	99.402	¼	60.48	291.04	¼	85.61	583.21	¼	110.741	975.91	¼	135.874	1469.14
⅜	10.603	8.9462	⅜	35.74	101.62	⅜	60.87	294.83	⅜	86.00	588.57	⅜	111.134	982.84	⅜	136.267	1477.64
½	10.996	9.6211	½	36.13	103.87	½	61.26	298.65	½	86.39	593.96	½	111.527	989.80	½	136.659	1486.17
⅝	11.388	10.321	⅝	36.52	106.14	⅝	61.65	302.49	⅝	86.79	599.37	⅝	111.919	996.78	⅝	137.052	1494.73
¾	11.781	11.045	¾	36.91	108.43	¾	62.05	306.35	¾	87.18	604.81	¾	112.312	1003.79	¾	137.445	1503.30
⅞	12.174	11.793	⅞	37.31	110.75	⅞	62.44	310.24	⅞	87.57	610.27	⅞	112.705	1010.82	⅞	137.837	1511.91
4	12.57	12.566	12	37.70	113.10	20	62.83	314.16	28	87.96	615.75	36	113.097	1017.87	44	138.230	1520.53
⅛	12.96	13.364	⅛	38.09	115.47	⅛	63.22	318.10	⅛	88.36	621.26	⅛	113.490	1024.96	⅛	138.523	1529.19
¼	13.35	14.186	¼	38.48	117.86	¼	63.62	322.06	¼	88.75	626.80	¼	113.883	1032.06	¼	139.015	1537.86
⅜	13.74	15.033	⅜	38.88	120.28	⅜	64.01	326.05	⅜	89.14	632.36	⅜	114.275	1039.19	⅜	139.408	1546.56
½	14.14	15.904	½	39.27	122.72	½	64.40	330.06	½	89.54	637.94	½	114.668	1046.34	½	139.801	1555.29
⅝	14.53	16.800	⅝	39.66	125.19	⅝	64.80	334.10	⅝	89.93	643.55	⅝	115.061	1053.52	⅝	140.194	1564.04
¾	14.92	17.721	¾	40.06	127.68	¾	65.19	338.16	¾	90.32	649.18	¾	115.454	1060.72	¾	140.586	1572.82
⅞	15.32	18.665	⅞	40.45	130.19	⅞	65.58	342.25	⅞	90.71	654.84	⅞	115.846	1067.96	⅞	140.979	1581.61
5	15.71	19.635	13	40.84	132.73	21	65.97	346.36	29	91.11	660.52	37	116.239	1075.21	45	141.372	1590.43
⅛	16.10	20.629	⅛	41.23	135.30	⅛	66.37	350.50	⅛	91.50	666.23	⅛	116.633	1082.49	⅛	141.764	1599.28
¼	16.49	21.648	¼	41.63	137.89	¼	66.76	354.66	¼	91.89	671.96	¼	117.024	1089.79	¼	142.157	1608.16
⅜	16.89	22.691	⅜	42.02	140.50	⅜	67.15	358.84	⅜	92.28	677.71	⅜	117.417	1097.11	⅜	142.550	1617.05
½	17.28	23.758	½	42.41	143.14	½	67.54	363.05	½	92.68	683.49	½	117.810	1104.46	½	142.942	1625.97
⅝	17.67	24.850	⅝	42.80	145.80	⅝	67.94	367.28	⅝	93.07	689.30	⅝	118.202	1111.84	⅝	143.335	1634.92
¾	18.06	25.967	¾	43.20	148.49	¾	68.33	371.54	¾	93.46	695.13	¾	118.596	1119.24	¾	143.728	1643.89
⅞	18.46	27.109	⅞	43.59	151.20	⅞	68.72	375.83	⅞	93.86	700.98	⅞	118.989	1126.66	⅞	144.121	1652.89
6	18.85	28.274	14	43.98	153.94	22	69.12	380.13	30	94.248	706.86	38	119.381	1134.11	46	144.513	1661.91
⅛	19.24	29.465	⅛	44.37	156.70	⅛	69.51	384.46	⅛	94.640	712.76	⅛	119.773	1141.59	⅛	144.906	1670.95
¼	19.63	30.680	¼	44.77	159.48	¼	69.90	388.82	¼	95.033	718.69	¼	120.166	1149.08	¼	145.299	1680.02
⅜	20.03	31.919	⅜	45.16	162.30	⅜	70.29	393.20	⅜	95.426	724.64	⅜	120.559	1156.61	⅜	145.691	1689.11
½	20.42	33.183	½	45.55	165.13	½	70.69	397.61	½	95.819	730.62	½	120.951	1164.15	½	146.084	1698.23
⅝	20.81	34.472	⅝	45.95	167.99	⅝	71.08	402.04	⅝	96.211	736.62	⅝	121.344	1171.73	⅝	146.477	1707.37
¾	21.21	35.785	¾	46.34	170.87	¾	71.47	406.49	¾	96.604	742.64	¾	121.737	1179.32	¾	146.869	1716.54
⅞	21.60	37.122	⅞	46.73	173.78	⅞	71.86	410.97	⅞	96.997	748 69	⅞	122.129	1186.94	⅞	147.262	1725.73
7	21.99	38.485	15	47.12	176.71	23	72.26	415.48	31	97.389	754.77	39	122.522	1194.59	47	147.655	1734.95
⅛	22.38	39.871	⅛	47.52	179.67	⅛	72.65	420.00	⅛	97.782	760.87	⅛	122.915	1202.26	⅛	148.048	1744.19
¼	22.78	41.282	¼	47.91	182.65	¼	73.04	424.56	¼	98.175	766.99	¼	123.308	1209.95	¼	148.440	1753.45
⅜	23.17	42.718	⅜	48.30	185.66	⅜	73.43	429.13	⅜	98.567	773.14	⅜	123.700	1217.67	⅜	148.833	1762.74
½	23.56	44.179	½	48.69	188.69	½	73.83	433.74	½	98.960	779.31	½	124.093	1225.42	½	149.226	1772.06
⅝	23.95	45.664	⅝	49.09	191.75	⅝	74.22	438.36	⅝	99.353	785.51	⅝	124.486	1233.18	⅝	149.618	1781.40
¾	24.35	47.173	¾	49.48	194.83	¾	74.61	443.01	¾	99.746	791.73	¾	124.878	1240.98	¾	150.011	1790.76
⅞	24.74	48.707	⅞	49.87	197.93	⅞	75.01	447.69	⅞	100.138	797.98	⅞	125.271	1248.79	⅞	150.404	1800.15

Table No. 72—Continued.

Diameters, Circumferences and Areas of Circles.

Advancing by 8ths.

Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.
48	150.796	1809.50	56	175.929	2463.0	64	201.062	3217.0	72	226.195	4071.5	80	251.327	5026.5	88	276.460	6082.1
⅛	151.189	1819.00	⅛	176.322	2474.0	⅛	201.455	3229.6	⅛	226.587	4085.7	⅛	251.720	5042.3	⅛	276.853	6099.4
¼	151.582	1828.45	¼	176.715	2485.1	¼	201.847	3242.2	¼	226.980	4099.8	¼	252.113	5058.0	¼	277.246	6116.7
⅜	151.975	1837.95	⅜	177.107	2496.1	⅜	202.240	3254.8	⅜	227.373	4114.0	⅜	252.506	5073.8	⅜	277.638	6134.1
½	152.367	1847.46	½	177.500	2507.2	½	202.633	3267.5	½	227.765	4128.2	½	252.898	5089.6	½	278.031	6151.4
⅝	152.760	1856.99	⅝	177.893	2518.3	⅝	203.025	3280.1	⅝	228.158	4142.5	⅝	253.291	5105.4	⅝	278.424	6168.8
¾	153.153	1866.55	¾	178.285	2529.4	¾	203.418	3292.8	¾	228.551	4156.8	¾	253.684	5121.2	¾	278.816	6186.2
⅞	153.545	1876.14	⅞	178.678	2540.6	⅞	203.811	3305.6	⅞	228.944	4171.1	⅞	254.076	5137.1	⅞	279.209	6203.7
49	153.938	1885.70	57	179.071	2551.8	65	204.204	3318.3	73	229.336	4185.4	81	254.469	5153.0	89	279.602	6221.1
⅛	154.331	1895.33	⅛	179.463	2563.0	⅛	204.596	3331.1	⅛	229.729	4199.7	⅛	254.862	5168.9	⅛	279.994	6238.6
¼	154.723	1905.04	¼	179.856	2574.2	¼	204.989	3343.9	¼	230.122	4214.1	¼	255.254	5184.9	¼	280.387	6256.1
⅜	155.116	1914.72	⅜	180.249	2585.4	⅜	205.382	3356.7	⅜	230.514	4228.5	⅜	255.647	5200.8	⅜	280.780	6273.7
½	155.509	1924.43	½	180.642	2596.7	½	205.774	3369.6	½	230.907	4242.9	½	256.040	5216.8	½	281.173	6291.2
⅝	155.902	1934.16	⅝	181.034	2608.0	⅝	206.167	3382.4	⅝	231.300	4257.4	⅝	256.433	5232.8	⅝	281.565	6308.8
¾	156.294	1943.91	¾	181 427	2619.4	¾	206.560	3395.3	¾	231.692	4271.8	¾	256.825	5248.9	¾	281.958	6326.4
⅞	156.687	1952.96	⅞	181.820	2630.7	⅞	206.952	3408.2	⅞	232.085	4286.3	⅞	257.218	5264.9	⅞	282.351	6344.1
50	157.080	1963.5	58	182.212	2642.1	66	207.345	3421.2	74	232.478	4300.8	82	257.611	5281.0	90	282.743	6361.7
⅛	157.472	1973.3	⅛	182.605	2653.5	⅛	207.738	3434.2	⅛	232.871	4315.4	⅛	258.003	5297.1	⅛	283.136	6379.4
¼	157.865	1983.2	¼	182.998	2664.9	¼	208.131	3447.2	¼	233.263	4329.9	¼	258.396	5313.3	¼	283.529	6397.1
⅜	158.258	1993.1	⅜	183.390	2676.4	⅜	208.523	3460.2	⅜	233.656	4344.5	⅜	258.789	5329.4	⅜	283.921	6414.9
½	158.650	2003.0	½	183.783	2687.8	½	208.916	3473.2	½	234.049	4359.2	½	259.181	5345.6	½	284.314	6432.6
⅝	159.043	2012.9	⅝	184.176	2699.3	⅝	209.309	3486.3	⅝	234.441	4373.8	⅝	259.574	5361.8	⅝	284.707	6450.4
¾	159.436	2022.8	¾	184.569	2710.9	¾	209.701	3499.4	¾	234.834	4388.5	¾	259.967	5378.1	¾	285.100	6468.2
⅞	159.829	2032.8	⅞	184.961	2722.4	⅞	210.094	3512.5	⅞	235.227	4403.1	⅞	260.359	5394.3	⅞	285.492	6486.0
51	160.221	2042.8	59	185.354	2734.0	67	210.487	3525.7	75	235.619	4417.9	83	260.752	5410.6	91	285.885	6503.9
⅛	160.614	2052.8	⅛	185.747	2745.6	⅛	210.879	3538.8	⅛	236.012	4432.6	⅛	261.145	5426.9	⅛	286.278	6521.8
¼	161.007	2062.9	¼	186.139	2757.2	¼	211.272	3552.0	¼	236.405	4447.4	¼	261.538	5443.3	¼	286.670	6539.7
⅜	161.399	2073.0	⅜	186.532	2768.8	⅜	211.665	3565.2	⅜	236.798	4466.2	⅜	261.930	5459.6	⅜	287.063	6557.6
½	161.792	2083.1	½	186.925	2780.5	½	212.058	3578.5	½	237.190	4477.0	½	262.323	5476.0	½	287.456	6575.5
⅝	162.185	2093.2	⅝	187.317	2792.2	⅝	212.450	3591.7	⅝	237.583	4491.8	⅝	262.716	5492.4	⅝	287.848	6593.5
¾	162.577	2103.3	¾	187.710	2803.9	¾	212.843	3605.0	¾	237.976	4506.7	¾	263.108	5508.8	¾	288.241	6611.5
⅞	162.970	2113.5	⅞	188.103	2815.7	⅞	213.236	3618.3	⅞	238.368	4521.5	⅞	263.501	5525.3	⅞	288.634	6629.6
52	163.363	2123.7	60	188.496	2827.4	68	213.628	3631.7	76	238.761	4536.5	84	263.894	5541.8	92	289.027	6647.6
⅛	163.756	2133.9	⅛	188.888	2839.2	⅛	214.021	3645.0	⅛	239.154	4551.4	⅛	264.286	5558.3	⅛	289.419	6665.7
¼	164.148	2144.2	¼	189.281	2851.0	¼	214.414	3658.4	¼	239.546	4566.4	¼	264.679	5574.8	¼	289.812	6683.8
⅜	164.541	2154.5	⅜	189.674	2862.9	⅜	214.806	3671.8	⅜	239.939	4581.3	⅜	265.072	5591.4	⅜	290.205	6701.9
½	164.934	2164.8	½	190.066	2874.8	½	215.199	3685.3	½	240.332	4596.3	½	265.465	5607.9	½	290.597	6720.1
⅝	165.326	2175.1	⅝	190.459	2886.6	⅝	215.592	3698.7	⅝	240.725	4611.4	⅝	265.857	5624.5	⅝	290.990	6738.2
¾	165.719	2185.4	¾	190.852	2898.6	¾	215.984	3712.2	¾	241.117	4626.4	¾	266.250	5641.2	¾	291.383	6756.4
⅞	166.112	2195.8	⅞	191.244	2910.5	⅞	216.377	3725.7	⅞	241.510	4641.5	⅞	266.643	5657.8	⅞	291.775	6774.7
53	166.504	2206.2	61	191.637	2922.5	69	216.770	3739.3	77	241.903	4656.6	85	267.035	5674.5	93	292.168	6792.9
⅛	166.897	2216.6	⅛	192.030	2934.5	⅛	217.163	3752.8	⅛	242.295	4671.8	⅛	267.428	5691.2	⅛	292.561	6811.2
¼	167.290	2227.0	¼	192.423	2946.5	¼	217.555	3766.4	¼	242.688	4689.9	¼	267.821	5707.9	¼	292.954	6829.5
⅜	167.683	2237.5	⅜	192.815	2958.5	⅜	217.948	3780.0	⅜	243.081	4702.1	⅜	268.213	5724.7	⅜	293.346	6847.8
½	168.075	2248.0	½	193.208	2970.6	½	218.341	3793.7	½	243.473	4717.3	½	268.606	5741.5	½	293.739	6868.1
⅝	168.468	2258.5	⅝	193.601	2982.7	⅝	218.733	3807.3	⅝	243.866	4732.5	⅝	268.999	5758.3	⅝	294.132	6884.5
¾	168.861	2269.1	¾	193.993	2994.8	¾	219.126	3821.0	¾	244.259	4747.8	¾	269.392	5775.1	¾	294.524	6902.9
⅞	169.253	2279.6	⅞	194.386	3006.9	⅞	219.519	3834.7	⅞	244.652	4763.1	⅞	269.784	5791.9	⅞	294.917	6921.3
54	169.646	2290.2	62	194.779	3019.1	70	219.911	3848.5	78	245.044	4778.4	86	270.177	5808.8	94	295.310	6939.8
⅛	170.039	2300.8	⅛	195.171	3031.3	⅛	220.304	3862.2	⅛	245.437	4793.7	⅛	270.570	5825.7	⅛	295.702	6958.2
¼	170.431	2311.5	¼	195.564	3043.5	¼	220.697	3876.0	¼	245.830	4809.0	¼	270.962	5842.6	¼	296.095	6976.7
⅜	170.824	2322.1	⅜	195.957	3055.7	⅜	221.090	3889.8	⅜	246.222	4824.4	⅜	271.355	5859.6	⅜	296.488	6995.3
½	171.217	2332.8	½	196.350	3068.0	½	221.482	3903.6	½	246.615	4839.8	½	271.748	5876.5	½	296.881	7013.8
⅝	171.609	2343.5	⅝	196.742	3080.3	⅝	221.875	3917.5	⅝	247.008	4855.2	⅝	272.140	5893.5	⅝	297.273	7032.4
¾	172.002	2354.3	¾	197.135	3092.6	¾	222.268	3931.4	¾	247.400	4870.7	¾	272.533	5910.6	¾	297.666	7051.0
⅞	172.395	2365.0	⅞	197.528	3104.9	⅞	222.660	3945.3	⅞	247.793	4886.2	⅞	272.926	5927.6	⅞	298.059	7069.6
55	172.788	2375.8	63	197.920	3117.2	71	223.053	3959.2	79	248.186	4901.7	87	273.319	5944.7	95	298.451	7088.2
⅛	173.180	2386.6	⅛	198.313	3129.6	⅛	223.446	3973.1	⅛	248.579	4917.2	⅛	273.711	5961.8	⅛	298.844	7106.9
¼	173.573	2397.5	¼	198.706	3142.0	¼	223.838	3987.1	¼	248.971	4932.7	¼	274.104	5978.9	¼	299.237	7125.6
⅜	173.966	2408.3	⅜	199.098	3154.5	⅜	224.231	4001.1	⅜	249.364	4948.3	⅜	274.497	5996.0	⅜	299.629	7144.3
½	174.358	2419.2	½	199.491	3166.9	½	224.624	4015.2	½	249.757	4963.9	½	274.889	6013.2	½	300.022	7163.0
⅝	174.751	2430.1	⅝	199.884	3179.4	⅝	225.017	4029.2	⅝	250.149	4979.5	⅝	275.282	6030.4	⅝	300.415	7181.8
¾	175.144	2441.1	¾	200.277	3191.9	¾	225.409	4043.3	¾	250.542	4995.2	¾	275.625	6047.6	¾	300.807	7200.6
⅞	175.536	2452.0	⅞	200.669	3204.4	⅞	225.802	4057.4	⅞	250.935	5010.9	⅞	276.067	6064.9	⅞	301.200	7219.4

FOUR 250 H. P. HEINE BOILERS, COMPANIA ELECTRICA DE FERROCARRILES, CHIHUAHUA, MEX., EQUIPPED WITH JONES UNDERFEED STOKERS.

Table No. 72—Continued.

Diameters, Circumferences and Areas of Circles.

Advancing by 8ths.

Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.
96	301.593	7238.2	3/4	303.949	7351.8	3/8	305.913	7447.1	98	307.876	7543.0	3/4	310.232	7658.9	3/8	312.196	7756.1
1/8	301.986	7257.1	7/8	304.342	7370.8	1/2	306.305	7466.2	1/8	308.269	7562.2	7/8	310.625	7678.3	1/2	312.588	7775 6
1/4	302.378	7276.0				5/8	306.698	7485.3	1/4	308.661	7581.5				5/8	312.981	7795.2
3/8	302.771	7294.9	97	304.734	7389.8	3/4	307.091	7504.5	3/8	309.054	7600.8	99	311.018	7697.7	3/4	313.374	7814.1
1/2	303.164	7313.8	1/8	305.127	7408.9	7/8	307.483	7523.7	1/2	309.447	7620.1	1/8	311.410	7717.1	7/8	313.767	7834.4
5/8	303.556	7333.8	1/4	305.520	7428.0				5/8	309.840	7639.5	1/4	311.803	7736.6	1 0	314.159	7854.0

BREWSTER & CO., CARRIAGE MFGRS. LONG ISLAND CITY, N. Y.
CONTAINS 525 H. P. OF HEINE BOILERS.

Table No. 73

Diameters, Circumferences and Areas of Circles.

Advancing by 10ths.

Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.
0.0	0.00000	0.000000	7.0	21.991	38.4845	14.0	43.982	153.938	21.0	65.973	346.361	28.0	87.965	615.752	35.0	109.96	962.113
0.1	0.31416	0.007854	1	22.305	39.5919	1	44.296	156.145	1	66.288	349.667	1	88.279	620.158	1	110.27	967.618
0.2	0.62832	0.031416	2	22.619	40.7150	2	44.611	158.368	2	66.602	352.989	2	88.593	624.580	2	110.58	973.140
0.3	0.94248	0.070686	3	22.934	41.8539	3	44.925	160.606	3	66.916	356.327	3	88.907	629.018	3	110.90	978.677
0.4	1.2566	0.125664	4	23.248	43.0084	4	45.239	162.860	4	67.230	359.681	4	89.221	633.471	4	111.21	984.230
0.5	1.5708	0.196350	5	23.562	44.1786	5	45.553	165.130	5	67.544	363.050	5	89.535	637.940	5	111.53	989.798
0.6	1.8850	0.282743	6	23.876	45.3646	6	45.867	167.415	6	67.858	366.435	6	89.850	642.424	6	111.84	995.382
0.7	2.1991	0.384845	7	24.190	46.5663	7	46.181	169.717	7	68.173	369.836	7	90.164	646.925	7	112.15	1000.98
0.8	2.5133	0.502655	8	24.504	47.7836	8	46.496	172.034	8	68.487	373.253	8	90.478	651.441	8	112.47	1006.60
0.9	2.8274	0.636173	9	24.819	49.0167	9	46.810	174.366	9	68.801	376.685	9	90.792	655.972	9	112.78	1012.23
1.0	3.1416	0.78540	8.0	25.133	50.2655	15.0	47.124	176.715	22.0	69.115	380.133	29.0	91.106	660.520	36.0	113.10	1017.87
1	3.4558	0.95033	1	25.447	51.5300	1	47.438	179.079	1	69.429	383.596	1	91.420	665.083	1	113.41	1023.54
2	3.7699	1.13097	2	25.761	52.8102	2	47.752	181.458	2	69.743	387.076	2	91.735	669.662	2	113.73	1029.21
3	4.0841	1.32732	3	26.075	54.1061	3	48.066	183.854	3	70.058	390.571	3	92.049	674.257	3	114.04	1034.91
4	4.3982	1.53938	4	26.389	55.4177	4	48.381	186.265	4	70.372	394.081	4	92.363	678.867	4	114.35	1040.62
5	4.7124	1.76715	5	26.704	56.7450	5	48.695	188.692	5	70.686	397.608	5	92.677	683.493	5	114.67	1046.34
6	5.0265	2.01062	6	27.018	58.0880	6	49.009	191.134	6	71.000	401.150	6	92.991	688.135	6	114.98	1052.09
7	5.3407	2.26980	7	27.332	59.4468	7	49.323	193.593	7	71.314	404.708	7	93.305	692.792	7	115.30	1057.84
8	5.6549	2.54469	8	27.646	60.8212	8	49.637	196.067	8	71.628	408.281	8	93.619	697.465	8	115.61	1063.62
9	5.9690	2.83529	9	27.960	62.2114	9	49.951	198.557	9	71.942	411.871	9	93.934	702.154	9	115.92	1069.40
2.0	6.2832	3.14159	9.0	28.274	63.6173	16.0	50.265	201.062	23.0	72.257	415.476	30.0	94.248	706.858	37.0	116.24	1075.21
1	6.5973	3.46361	1	28.588	65.0388	1	50.580	203.583	1	72.571	419.096	1	94.562	711.579	1	116.55	1081.03
2	6.9115	3.80133	2	28.903	66.4761	2	50.894	206.120	2	72.885	422.733	2	94.876	615.315	2	116.87	1086.86
3	7.2257	4.15476	3	29.217	67.9291	3	51.208	208.672	3	73.199	426.385	3	95.190	721.066	3	117.18	1092.71
4	7.5398	4.52389	4	29.531	69.3978	4	51.522	211.241	4	73.513	430.053	4	95.504	725.834	4	117.50	1098.58
5	7.8540	4.90874	5	29.845	70.8822	5	51.836	213.825	5	73.827	433.736	5	95.819	730.617	5	117.81	1104.46
6	8.1681	5.30929	6	30.159	72.3823	6	52.150	216.424	6	74.142	437.435	6	96.133	735.415	6	118.12	1110.36
7	8.4823	5,72555	7	30.473	73.8981	7	52.465	219.040	7	74.456	441.150	7	96.447	740.230	7	118.44	1116.28
8	8.7965	6.15752	8	30.788	75.4296	8	52.779	221.671	8	74.770	444.881	8	96.761	745.060	8	118.75	1122.21
9	9.1106	6.60520	9	31.102	76.9769	9	53.093	224.318	9	75.084	448.627	9	97.075	749.906	9	119.07	1128.15
3.0	9.4248	7.06858	10.0	31.416	78.5398	17.0	53.407	226.980	24.0	75.398	452.389	31.0	97.389	754.768	38.0	119.38	1134.11
1	9.7389	7.54768	1	31.730	80.1185	1	53.721	229.658	1	75.712	456.167	1	97.704	759.645	1	119.69	1140.09
2	10.053	8.04248	2	32.044	81.7128	2	54.035	232.352	2	76.027	459.961	2	98.018	764.538	2	120.01	1146.08
3	10.367	8.55299	3	32.358	83.3229	3	54.350	235.062	3	76.341	463.770	3	98.332	769.447	3	120.32	1152.09
4	10.681	9.07920	4	32.673	84.9487	4	54.664	237.787	4	76.655	467.595	4	98.646	774.371	4	120.64	1158.11
5	10.996	9.62113	5	32.987	86.5901	5	54.978	240.528	5	76.969	471.435	5	98.960	779.311	5	120.95	1164.15
6	11.310	10.1788	6	33.301	88.2473	6	55.292	243.285	6	77.283	475.292	6	99.274	784.267	6	121.27	1170.21
7	11.624	10.7521	7	33.615	89.9202	7	55.606	246.057	7	77.597	479.164	7	99.588	789.239	7	121.58	1176.28
8	11.938	11.3411	8	33.929	91.6088	8	55.920	248.846	8	77.912	483.051	8	99.903	794.226	8	121.89	1182.37
9	12.252	11.9459	9	34.243	93,3132	9	56.235	251.649	9	78.226	486.955	9	100.22	799.229	9	122.11	1188.47
4.0	12.566	12.5664	11.0	34.558	95.0332	18.0	56.549	254.469	25.0	78.540	490.874	32.0	100.53	804.248	39.0	122.52	1194.59
1	12.881	13.2025	1	34.872	96.7689	1	56.863	257.304	1	78.854	494.809	1	100.85	809.282	1	122.84	1200.72
2	13.195	13.8544	2	35.186	98.5203	2	57.177	260.155	2	79.168	498.759	2	101.16	814.332	2	123.15	1206.87
3	13.509	14.5220	3	35.500	100.287	3	57.491	263.022	3	79.482	502.726	3	101.47	819.398	3	123.46	1213.04
4	13.823	15.2053	4	35.814	102.070	4	57.805	265.904	4	79.796	506.707	4	101.79	824.480	4	123.78	1219.22
5	14.137	15.9043	5	36.128	103.869	5	58.119	268.803	5	80.111	510.705	5	102.10	829.577	5	124.09	1225.42
6	14.451	16.6190	6	36.442	105.683	6	58.434	271.716	6	80.425	514.719	6	102.42	834.690	6	124.41	1231.63
7	14.765	17.3494	7	36.757	107.513	7	58.748	274.646	7	80.739	518.748	7	102.73	839.818	7	124.72	1237.86
8	15.080	18.0956	8	37.071	109.359	8	59.062	277.591	8	81.053	522.792	8	103.04	844.963	8	125.04	1244.10
9	15.394	18.8574	9	37.385	111.220	9	59.376	280.552	9	81.369	526.853	9	103.36	850.123	9	125.35	1250.36
5.0	15.708	19.6350	12.0	37.699	113.097	19.0	59.690	283.529	26.0	81.681	530.929	33.0	103.67	855.299	40,0	125,66	1256,64
1	16.022	20.4282	1	38.013	114.990	1	60.004	286.521	1	81.996	535.021	1	103.99	860.490	1	125.98	1262.93
2	16.336	21.2372	2	38.327	116.899	2	60.319	289.529	2	82.310	539.129	2	104.30	865.697	2	126.29	1269.23
3	16.650	22.0618	3	38.642	118.823	3	60.633	292.553	3	82.624	543.252	3	104.62	870.920	3	126.61	1275.56
4	16.965	22.9022	4	38.956	120.763	4	60.947	295.592	4	82.938	547.391	4	104.93	876.159	4	126.92	1281.90
5	17.279	23.7583	5	39.270	122.718	5	61.261	298.648	5	83.252	551.546	5	105.24	881.413	5	127.23	1288.25
6	17.593	24.6301	6	39.584	124.690	6	61.575	301.719	6	83.566	555.716	6	105.56	886.683	6	127.55	1294.62
7	17.907	25.5176	7	39.898	126.677	7	61.889	304.805	7	83.881	559.903	7	105.87	891.969	7	127.86	1301.00
8	18.221	26.4208	8	40.212	128.680	8	62.204	307.907	8	84.195	564.104	8	106.19	897.270	8	128.18	1307.41
9	18.535	27.3397	9	40.527	130.698	9	62.518	311.026	9	84.569	568.322	9	106.50	902.587	9	128.49	1313.82
6.0	18.850	28.2743	13.0	40.841	132.732	20.0	62.832	314.159	27.0	84.823	572.555	34.0	106.81	907.920	41.0	128.81	1320.25
1	19.164	29.2247	1	41.155	134.782	1	63.146	317.309	1	85.137	576.804	1	107.13	913.269	1	129.12	1326.70
2	19.478	30.1907	2	41.469	136.848	2	63.460	320.474	2	85.451	581.069	2	107.44	918.633	2	129.43	1333.17
3	19.792	31.1725	3	41.783	138.929	3	63.774	323.655	3	85.766	585.349	3	107.76	924.013	3	129.75	1339.65
4	20.106	32.1699	4	42.097	141.026	4	64.088	326.851	4	86.080	589.646	4	108.07	929.409	4	130.06	1346.14
5	20.420	33.1831	5	42.412	143.139	5	64.403	330.064	5	86.394	593.957	5	108.38	934.820	5	130.38	1352.65
6	20.735	34.2119	6	42.726	145.267	6	64.717	333.292	6	86.708	598.285	6	108.70	940.247	6	130.69	1359.18
7	21.049	35.2565	7	43.040	147.411	7	65.031	336.535	7	87.022	602.628	7	109.01	945.690	7	131.00	1365.72
8	21.363	36.3168	8	43.354	149.571	8	65.345	339.795	8	87.336	606.987	8	109.33	951.149	8	131.32	1372.28
9	21.677	37.3928	9	43.668	151.747	9	65.659	343.070	9	87.650	611.362	9	109.64	956.623	9	131.63	1378.85

Table No. 73—Continued.

Diameters, Circumferences and Areas of Circles.

Advancing by 10ths.

Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.
42.0	131.95	1385.44	49.0	153.94	1885.74	56.0	175.93	2463.01	63.0	197.92	3117.25	70.0	219.91	3848.45	77.0	241.90	4656.63
1	132.26	1392.05	1	154.25	1893.45	1	176.24	2471.81	1	198.24	3127.15	1	220.23	3859.45	1	242.22	4668.73
2	132.58	1398.67	2	154.57	1901.17	2	176.56	2480.63	2	198.55	3137.07	2	220.54	3870.47	2	242.53	4680.85
3	132.89	1405.31	3	154.88	1908.90	3	176.87	2489.47	3	198.86	3147.00	3	220.85	3881.51	3	242.85	4692.98
4	133.20	1411.96	4	155.19	1916.65	4	177.19	2498.32	4	199.18	3156.96	4	221.17	3892.56	4	243.16	4705.13
5	133.52	1418.63	5	155.51	1924.42	5	177.50	2507.19	5	199.49	3166.92	5	221.48	3903.63	5	243.47	4717.30
6	133.83	1425.31	6	155.82	1932.21	6	177.81	2516.07	6	199.81	3176.90	6	221.80	3914.71	6	243.79	4729.48
7	134.15	1432.01	7	156.14	1940.00	7	178.13	2524.97	7	200.12	3186.90	7	222.11	3925.80	7	244.10	4741.68
8	134.46	1438.72	8	156.45	1947.82	8	178.44	2533.88	8	200.42	3196.92	8	222.43	3936.92	8	244.42	4753.89
9	134.77	1445.45	9	156.77	1955.65	9	178.76	2542.81	9	200.75	3206.95	9	222.74	3948.05	9	244.73	4766.12
43.0	135.09	1452.20	50.0	157.08	1963.50	57.0	179.07	2551.76	64.0	201.06	3216.99	71.0	223.05	3959.19	78.0	245.04	4778.36
1	135.40	1458.93	1	157.39	1971.36	1	179.39	2560.72	1	201.38	3227.05	1	223.37	3970.35	1	245.36	4790.62
2	135.72	1465.74	2	157.71	1979.23	2	179.70	2569.70	2	201.69	3237.13	2	223.68	3981.53	2	245.67	4802.90
3	136.03	1472.54	3	158.02	1987.13	3	180.01	2578.69	3	202.00	3247.22	3	224.00	3992.72	3	245.99	4815.19
4	136.35	1479.34	4	158.34	1995.04	4	180.33	2587.70	4	202.32	3257.33	4	224.31	4003.92	4	246.30	4827.50
5	136.66	1486.17	5	158.65	2002.96	5	180.64	2596.72	5	202.63	3267.45	5	224.62	4015.15	5	246.62	4839.82
6	136.97	1493.01	6	158.97	2010.90	6	180.96	2605.76	6	202.95	3277.59	6	224.94	4026.39	6	246.93	4852.16
7	137.29	1499.87	7	159.28	2018.86	7	181.27	2614.82	7	203.26	3287.75	7	225.25	4037.65	7	247.24	4864.51
8	137.60	1506.74	8	159.59	2026.83	8	181.58	2623.89	8	203.58	3297.92	8	225.57	4048.92	8	247.56	4876.88
9	137.92	1513.63	9	159.91	2034.82	9	181.90	2632.98	9	203.89	3308.10	9	225.88	4060.20	9	247.87	4889.27
44.0	138.23	1520.53	51.0	160.22	2042.82	58.0	182.21	2642.08	65.0	204.20	3318.31	72.0	226.19	4071.50	79.0	248.19	4901.67
1	138.54	1527.45	1	160.54	2050.84	1	182.53	2651.20	1	204.50	3328.53	1	226.51	4082.82	1	248.50	4914.09
2	138.86	1534.39	2	160.85	2058.87	2	182.84	2660.33	2	204.83	3338.76	2	226.82	4094.16	2	248.81	4926.52
3	139.17	1541.34	3	161.16	2066.92	3	183.16	2669.48	3	205.15	3349.01	3	227.14	4105.50	3	249.13	4938.97
4	139.49	1548.30	4	161.48	2074.99	4	183.47	2678.65	4	205.46	3359.27	4	227.45	4116.87	4	249.44	4951.43
5	139.80	1555.28	5	161.79	2083.07	5	183.78	2687.83	5	205.77	3369.55	5	227.77	4128.25	5	249.76	4963.91
6	140.12	1562.28	6	162.11	2091.17	6	184.10	2697.01	6	206.09	3379.85	6	228.08	4139.65	6	250.07	4976.41
7	140.43	1569.30	7	162.42	2099.28	7	184.41	2706.24	7	206.40	3390.16	7	228.39	4151.06	7	250.38	4988.92
8	140.74	1576.33	8	162.73	2107.41	8	184.73	2715.47	8	206.72	3400.49	8	228.71	4162.48	8	250.70	5001.45
9	141.06	1583.37	9	163.05	2115.56	9	185.04	2724.71	9	207.03	3410.84	9	229.02	4173.93	9	251.01	5013.99
45.0	141.37	1590.43	52.0	163.36	2123.72	59.0	185.35	2733.97	66.0	207.35	3421.19	73.0	229.34	4185.39	80.0	251.33	5026.55
1	141.69	1597.51	1	163.68	2131.89	1	185.67	2743.25	1	207.66	3431.57	1	229.65	4196.86	1	251.64	5039.12
2	142.00	1604.60	2	163.98	2140.08	2	185.98	2752.54	2	207.97	3441.96	2	229.97	4208.35	2	251.96	5051.71
3	142.31	1611.71	3	164.31	2148.29	3	186.30	2761.84	3	208.28	3452.37	3	230.28	4219.86	3	252.27	5064.32
4	142.63	1618.83	4	164.62	2156.51	4	186.61	2771.17	4	208.60	3462.79	4	230.59	4231.38	4	252.58	5076.94
5	142.94	1625.97	5	164.93	2164.75	5	186.93	2780.51	5	208.92	3473.23	5	230.91	4242.93	5	252.90	5089.58
6	143.26	1633.13	6	165.25	2173.01	6	187.24	2789.86	6	209.23	3483.68	6	231.22	4254.48	6	253.21	5102.23
7	143.57	1640.30	7	165.56	2181.28	7	187.55	2799.23	7	209.54	3494.15	7	231.54	4266.04	7	253.53	5114.90
8	143.89	1647.48	8	165.88	2189.56	8	187.87	2808.62	8	209.86	3504.64	8	231.85	4277.62	8	253.84	5127.58
9	144.20	1654.68	9	166.19	2197.87	9	188.18	2818.02	9	210.17	3515.14	9	232.16	4289.22	9	254.15	5140.28
46.0	144.51	1661.90	53.0	166.50	2290.22	60.0	188.50	2827.43	67.0	210.49	3525.65	74.0	232.48	4300.84	81.0	254.47	5153.00
1	144.83	1669.14	1	166.82	2298.71	1	188.81	2836.87	1	210.80	3536.18	1	232.79	4312.47	1	254.78	5165.73
2	145.14	1676.39	2	167.13	2307.22	2	189.12	2846.31	2	211.12	3546.73	2	233.11	4324.12	2	255.10	5178.48
3	145.46	1683.65	3	167.45	2315.74	3	189.44	2855.78	3	211.43	3557.30	3	233.42	4335.78	3	255.41	5191.24
4	145.77	1690.93	4	167.76	2324.28	4	189.75	2865.26	4	211.74	3567.88	4	233.73	4347.46	4	255.73	5204.02
5	146.08	1698.23	5	168.08	2332.83	5	190.07	2874.75	5	212.06	3578.47	5	234.05	4359.16	5	256.04	5216.81
6	146.40	1705.54	6	168.39	2341.40	6	190.38	2884.26	6	212.37	3589.08	6	234.36	4370.87	6	256.35	5229.62
7	146.71	1712.87	7	168.70	2349.98	7	190.70	2893.79	7	212.69	3599.71	7	234.68	4382.59	7	256.67	5242.45
8	147.03	1720.21	8	169.02	2358.58	8	191.01	2903.33	8	213.00	3610.35	8	234.99	4394.33	8	256.98	5255.29
9	147.34	1727.57	9	169.33	2367.20	9	191.32	2912.89	9	213.31	3621.01	9	235.31	4406.09	9	257.30	5268.14
47.0	147.65	1734.94	54.0	169.65	2375.83	61.0	191.64	2922.47	68.0	213.36	3631.68	75.0	235.62	4417.86	82.0	257.76	5281.02
1	147.97	1742.34	1	169.96	2384.48	1	191.95	2932.06	1	213.94	3642.37	1	235.93	4429.65	1	257.92	5293.91
2	148.28	1749.74	2	170.27	2393.14	2	192.27	2941.66	2	214.26	3653.08	2	236.25	4441.46	2	258.24	5306.81
3	148.60	1757.16	3	170.59	2401.82	3	192.58	2951.28	3	214.57	3663.80	3	236.56	4453.28	3	258.55	5319.73
4	148.91	1764.60	4	170.90	2410.51	4	192.89	2960.92	4	214.89	3674.53	4	236.88	4465.11	4	258.87	5332.67
5	1 9.23	1772.05	5	171.22	2419.22	5	193.21	2970.57	5	215.20	3685.28	5	237.19	4476.97	5	259.18	5345.62
6	149.54	1779.52	6	171.53	2427.95	6	193.52	2980.24	6	215.51	3696.05	6	237.50	4488.83	6	259.50	5358.58
7	149.85	1787.01	7	171.85	2436.69	7	193.84	2989.92	7	215.83	3706.84	7	237.82	4500.72	7	259.81	5371.57
8	150.17	1794.51	8	172.16	2445.45	8	194.15	2999.62	8	216.14	3717.64	8	238.13	4512.62	8	260.12	5384.56
9	150.48	1802.03	9	172.47	2454.22	9	194.47	3009.34	9	216.46	3728.45	9	238.45	4524.53	9	260.44	5397.58
48.0	150.80	1809.56	55.0	172.79	2463.01	62.0	194.78	3019.07	69.0	216.67	3739.28	76.0	238.76	4536.46	83.0	260.75	5410.61
1	151.11	1817.11	1	173.10	2471.81	1	195.09	3028.82	1	217.08	3750.13	1	239.08	4548.41	1	261.07	5423.65
2	151.43	1824.67	2	173.42	2480.63	2	195.41	3038.58	2	217.40	3760.99	2	239.39	4560.37	2	261.38	5436.71
3	151.74	1832.25	3	173.73	2489.47	3	195.72	3048.36	3	217.71	3771.87	3	239.70	4572.34	3	261.69	5449.79
4	152.05	1839.84	4	174.04	2498.32	4	196.04	3058.15	4	218.03	3782.76	4	240.02	4584.34	4	262.01	5462.88
5	152.37	1847.45	5	174.36	2507.19	5	196.35	3067.96	5	218.34	3793.67	5	240.33	4596.35	5	262.32	5475.99
6	152.68	1855.08	6	174.67	2516.07	6	196.66	3077.79	6	218.66	3804.59	6	240.65	4608.37	6	262.64	5489.12
7	153.00	1862.72	7	174.99	2524.97	7	196.98	3087.63	7	218.97	3815.54	7	240.96	4620.42	7	262.95	5502.26
8	153.31	1870.38	8	175.30	2533.88	8	197.29	3097.48	8	219.28	3826.49	8	241.27	4632.47	8	263.27	5515.41
9	153.62	1878.05	9	175.62	2542.81	9	179.69	3107.36	9	219.60	3837.46	9	241.59	4644.54	9	263.58	5528.58

KEENAN BUILDING, PITTSBURG, PA.,
CONTAINS 885 H. P. OF HEINE BOILERS.

Table No. 73—Continued.

Diameters, Circumferences and Areas of Circles.

Advancing by 10ths.

Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.
84.0	263.89	5541.77	87.0	273.32	5944.68	90.0	282.74	6361.73	93.0	292.17	6792.91	96.0	301.59	7238.23	98.0	307.88	7542.96
1	264.21	5554.97	1	273.63	5958.35	1	283.06	6375.87	1	292.48	6807.52	1	301.91	7253.32	1	308.19	7558.37
2	264.52	5568.19	2	273.95	5972.04	2	283.37	6390.03	2	292.80	6822.16	2	302.22	7268.42	2	308.50	7573.78
3	264.84	5581.42	3	274.26	5985.75	3	283.69	6404.21	3	293.11	6836.80	3	302.54	7283.54	3	308.82	7589.22
4	265.15	5594.67	4	274.58	5999.47	4	284.00	6418.40	4	293.42	6851.47	4	302.85	7298.67	4	309.13	7604.66
5	265.46	5607.94	5	274.89	6013.20	5	284.31	6432.61	5	293.74	6866.15	5	303.16	7313.82	5	309.45	7620 13
6	265.78	5621.22	6	275.20	6026.96	6	284.63	6446.83	6	294.05	6880.84	6	303.48	7328.99	6	309.76	7635.61
7	266.09	5634.52	7	275.52	6040.73	7	284.94	6461.07	7	294.37	6895.55	7	303.79	7344.17	7	310.08	7651.11
8	266.41	5647.83	8	275.83	6054.51	8	285.26	6475.33	8	294.68	6910.28	8	304.11	7359.37	8	310.39	7666.62
9	266.72	5661.16	9	276.15	6068.31	9	285.57	6489.60	9	295.00	6925.02	9	304.42	7374.58	9	310.70	7682.14
85.0	267.04	5674.50	88.0	276.46	6082.12	91.0	285.88	6503.88	94.0	295.31	6939.78	97.0	304.73	7389.81	99.0	311.02	7697.69
1	267.35	5687.86	1	276.77	6095.95	1	286.20	6518.18	1	295.62	6954.55	1	305.05	7405.06	1	311.33	7713.25
2	267.66	5701.24	2	277.09	6109.80	2	286.51	6532.50	2	295.94	6969.34	2	305.36	7420.32	2	311.65	7728.32
3	267.98	5714.63	3	277.40	6123.66	3	286.83	6546.84	3	296.25	6984.15	3	305.68	7435.59	3	311.96	7744.41
4	268.29	5728.03	4	277.72	6137.54	4	287.14	6561.18	4	296.57	6998.97	4	305.99	7450.88	4	312.27	7760.02
5	268.61	5741.46	5	278.03	6151.43	5	287.46	6575.55	5	296.88	7013.80	5	306.31	7466.19	5	312.59	7775.64
6	268.92	5754.90	6	278.35	6165.34	6	287.77	6589.93	6	297.19	7028.65	6	306 62	7481.51	6	312.90	7791.28
7	269.23	5768.35	7	278.66	6179.27	7	288.08	6604.33	7	297.51	7043.52	7	306.93	7496.85	7	313.22	7806.93
8	269.55	5781.82	8	278.97	6193.21	8	288.40	6618.74	8	297.82	7058.40	8	307.25	7512.21	8	313.53	7822.60
9	269.86	5795.30	9	279.29	6207.17	9	288.71	6633.17	9	298.14	7073.30	9	307.56	7527.57	9	313.85	7838.28
															100.0	314.16	7854.00
86.0	270.18	5808.80	89.0	279.60	6221.14	92.0	289.03	6647.61	95.0	298.45	7088.22						
1	270.49	5822.32	1	279.92	6235.13	1	289.34	6662.07	1	298.77	7103.15						
2	270.81	5835.85	2	280.23	6249.13	2	289.65	6676.54	2	299.08	7118.09						
3	271.12	5849.40	3	280.54	6263.15	3	289.97	6691.03	3	299.39	7133.06						
4	271.43	5862.97	4	280.86	6277.18	4	290.28	6705.54	4	299.71	7148.03						
5	271.75	5876.55	5	281.17	6291.24	5	290.60	6720.06	5	300.02	7163.03						
6	272.06	5890.14	6	281.49	6305.30	6	290.91	6734.60	6	300.34	7178.04						
7	272.38	5903.75	7	281.80	6319.38	7	291.23	6749.15	7	300.65	7193.06						
8	272.69	5917.38	8	282.12	6333.48	8	291.54	6763.72	8	300.96	7208.10						
9	273.00	5931.02	9	282.43	6347.60	9	291.85	6778.31	9	301.28	7223.16						

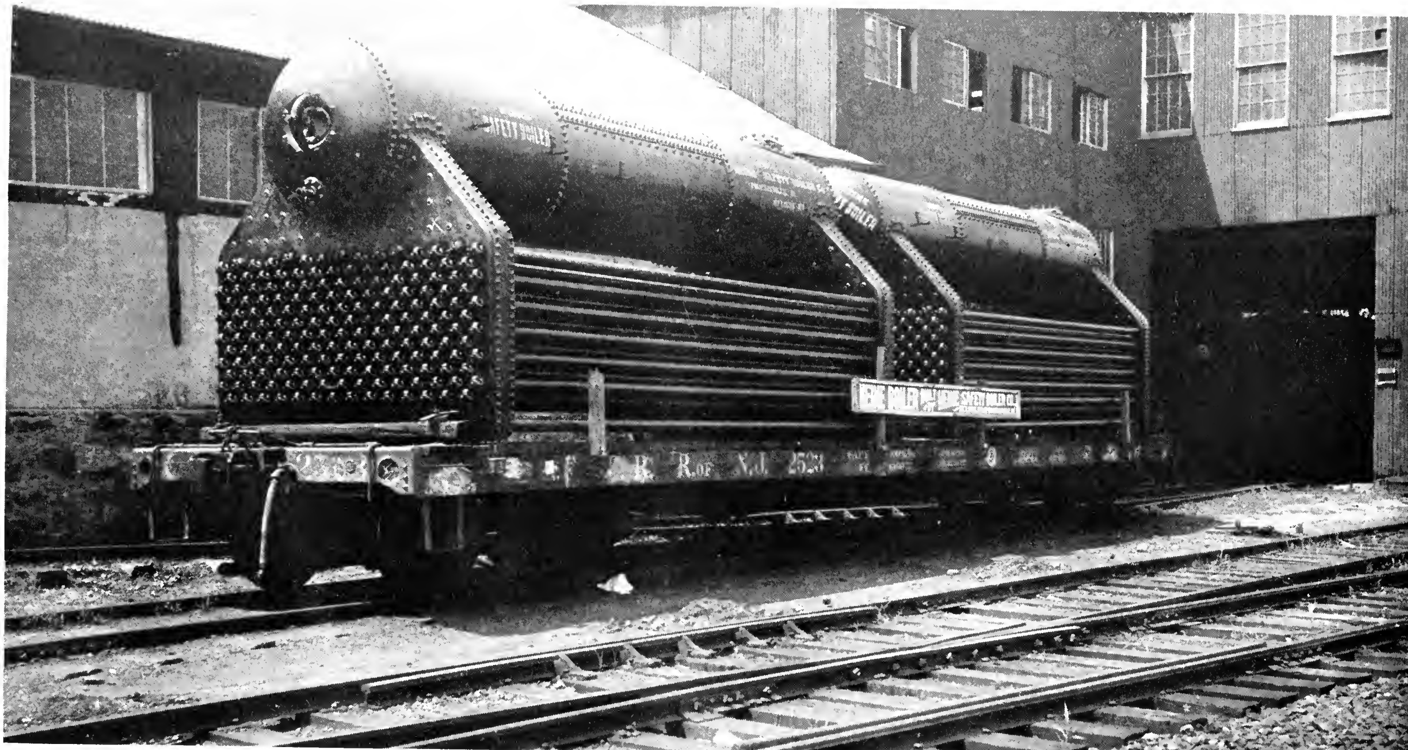
FOUR 492 H. P. HEINE BOILERS, SUMITOMO BESSHI MINES, JAPAN.

2800 H. P. OF HEINE BOILERS, W. C. HAMILTON AND SONS' PAPER MILL, PHILADELPHIA, PA., EQUIPPED WITH HAWLEY DOWN DRAFT FURNACES.

Table No. 74

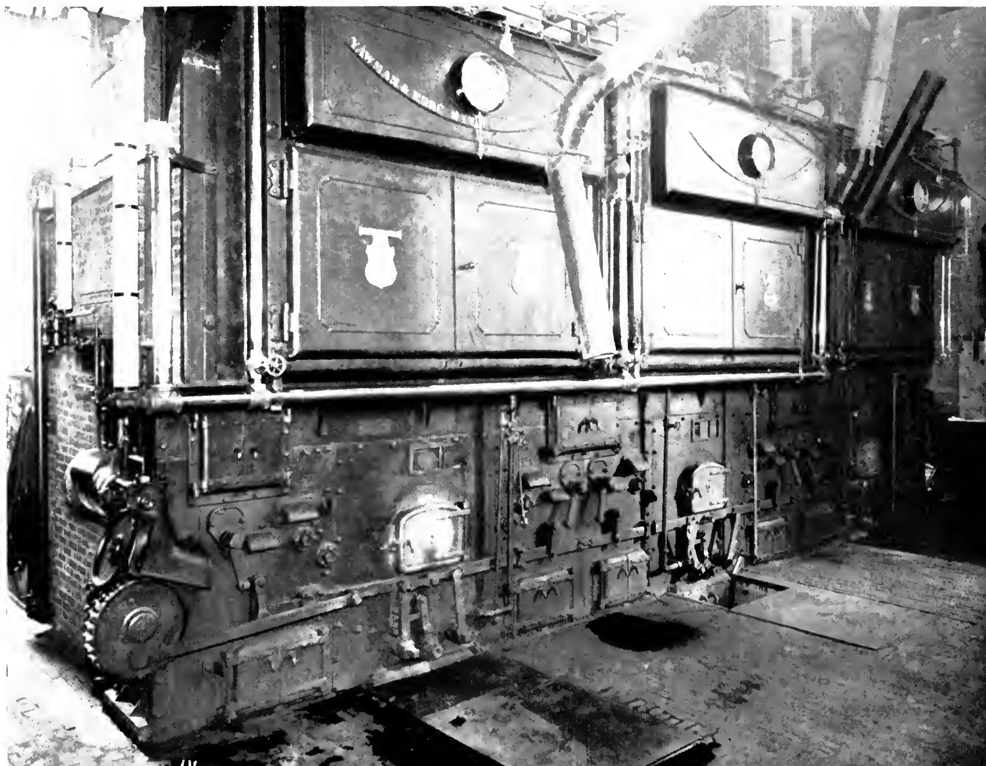
Diameters and Circumferences of Circles, and the Contents in Gallons for One Foot of Depth.

Diameter.		Circum.		Area in sq. feet.	Gallons. 1 Ft. Depth.
Ft.	In.	Ft.	In.		
4		12	6¾	12.56	93.97
4	1	12	9⅞	13.09	97.93
4	2	13	1	13.63	101.97
4	3	13	4⅛	14.18	103.03
4	4	13	7¼	14.74	110.29
4	5	13	10½	15.32	114.57
4	6	14	1⅝	15.90	118.93
4	7	14	4⅝	16.49	123.38
4	8	14	7⅞	17.10	127.91
4	9	14	11	17.72	132.52
4	10	15	2⅛	18.34	137 21
4	11	15	5¼	18.98	142.05
5		15	8½	19.63	146.83
5	1	15	11⅝	20.29	151.77
5	2	16	2¾	20.96	156.78
5	3	16	5¾	21.64	161.88
5	4	16	9	22.34	167.06
5	5	17	0⅛	23.04	172.33
5	6	17	3¼	23.75	177.67
5	7	17	6⅜	24.48	183.09
5	8	17	9⅝	25.21	188.60
5	9	18	0¾	25.96	194.19
5	10	18	3⅞	26.72	199.86
5	11	18	7⅛	27.49	205.61
6		18	10⅛	28.27	211.44
6	3	19	7½	30.67	229.43
6	6	20	4⅞	33.18	248.15
6	9	21	2⅜	35.78	267.61
7		21	11⅞	38.48	287.80
7	3	22	9¼	41.28	308.72
7	6	23	6¾	44.17	330.38
7	9	24	4⅛	47.17	352.76
8		25	1½	50.26	375.90
8	3	25	11	53.45	399.76
8	6	26	8⅜	56.74	424.36
8	9	27	5¾	60.13	449.21
9		28	3¼	63.61	475.75
9	3	29	0⅝	67.20	502.55
9	6	29	10⅛	70.88	530.08
9	9	30	7½	74.66	558.35
10		31	5	78.54	587.35
10	3	32	2⅜	82.51	617.08
10	6	32	11¾	86.59	647.55
10	9	33	9¼	90.76	678.27
11		34	6⅝	95.03	710.69
11	3	35	4⅛	99.40	743.36
11	6	36	1½	103.86	776.77
11	9	36	10⅞	108.43	810.91
12		37	8⅜	113.09	848.18
12	3	38	5¾	117.85	881.39
12	6	39	3¼	122.71	917.73
12	9	40	0⅝	127.67	954.81
13		40	10	132.73	992.62
13	3	41	7½	137.88	1031.17
13	6	42	4⅞	143.13	1070 45
13	9	43	2¼	148.48	1108.06
14		43	11¾	153.93	1151.21
14	3	44	9⅛	159.48	1192.69
14	6	45	6⅝	165.13	1234.91
14	9	46	4	170.87	1277.86
15		47	1½	176.71	1321.54
15	3	47	10⅞	182.65	1365.96
15	6	48	8¼	188.69	1407.51
15	9	49	5¾	194.82	1457.00
16		50	3⅛	201.06	1503.62
16	3	51	0½	207.39	1550.97
16	6	51	10	213.82	1599.06
16	9	52	7⅜	220.35	1647.89
17		53	4⅞	226.98	1697.45
17	3	54	2⅛	233.70	1747.74
17	6	54	11⅝	240.52	1798.76
17	9	55	9⅛	247.45	1850.53
18		56	6½	254.46	1903.02
18	3	57	4	261.58	1965.25
18	6	58	1⅜	268.80	2010.21
18	9	58	10¾	276.11	2064.91
19		59	8¼	283.52	2120.34
19	3	60	5⅝	291.03	2176.51
19	6	61	3⅛	298.64	2233.29
10	9	62	0½	306.35	2291.04
20		62	9⅞	314.16	2349.41
20	3	63	7⅜	322.06	2408.51
20	6	64	4¾	330.06	2468.35
20	9	65	2¼	338.16	2528.92
21		65	11⅜	346.36	2590.22
21	3	66	9	354.65	2652.25
21	6	67	6½	363.05	2715.04
21	9	68	3⅞	371.54	2778.54
22		69	1⅜	380.13	2842.79
22	3	69	10¾	388.82	2907.76
22	6	70	8¼	397.60	2973.48
22	9	71	5⅝	406.49	3039.92
23		72	3	415.47	3107.10
23	3	73	0½	424.55	3175.01
23	6	73	9⅞	433.73	3243.65
23	9	74	7¼	443.01	3313.04
24		75	4¾	452.39	3383.15
24	3	76	2⅛	461.86	3454.00
24	6	76	11⅝	471.43	3525.59
24	9	77	9	481.10	3597.90
25		78	6⅜	490.87	3670.95
25	3	79	3⅞	500.74	3744.74
25	6	80	1¼	510.70	3819.26
25	9	80	10¾	520.76	3894.52



TWO 338 H. P. HEINE BOILERS FOR ONEITA KNITTING MILLS, READY TO ERECT AS SOON AS DELIVERED.

Index.



THREE 250 H. P. HEINE BOILERS, YAWMAN AND ERBE MFG. CO., ROCHESTER, N. Y., EQUIPPED WITH MURPHY FURNACES.

Index.

Concluded

HELIOS